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Role of demonstration projects in innovation: transition to sustainable energy and transport

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Table of Contents

Andersen, Allan Dahl	1
Backhaus, Julia	30
Bakker, Sjoerd	46
Barbier, Marc	69
Blum, Nicole Ursina	87
Bolton, Ronan	105
Bono, Federica	123
Bos, Annette	145
Bosman, Rick	158
Chandrashekeran, Sangeetha	182
de Haan, Fjalar J.	209
Doci, Gabriella	221
Erlinghagen, Sabine	243
Farla, Jacco C.M	272
Ferguson, Briony Cathryn	296
Fontes, Margarida	314
Frantzeskaki, Niki	345
Fratini, Chiara Farné	364
Fuchs, Gerhard	387
Gosens, Jorrit	412
Hanson, Jens	443
Happaerts, Sander	505
Horbach, Jens	525
Huijben, Josephina Cornelia Catharina Maria	569
Jensen, Jens Stissing	586
Jhagroe, Shivant Sandesh	600
Jørgensen, Urlik	627
Klitkou, Antje	638
Koch, Christian	665
Kronsell, Annica	683
Liedtke, Christa	702
Markard, Jochen	730
Martin, Hanna	755
Mattes, Jannika	770
Melamu, Rethabile Bonang	786
Mercure, Jean-Francois	809
Normann, Håkon	835
Penna, Caetano	855
Riddell, Darcy Jane	895
Rogge, Karoline	925
Schepelmann, Philipp	973
Sengers, Frans	1000
Seyfang, Gill	1028
Søndergaard, Bent	1052

Spaeth, Philipp	1072
Switzer, Andrew	1084
Truffer, Bernhard	1120
van der Blonk, Heico	1160
Verhees, Bram	1172
Walz, Rainer	1198
Wehrmeyer, Walter	1217

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"The role of infrastructure in innovation-system building and transformation in the context of a pending low-carbon transition"

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Abstract
A transition to a low-carbon society involves innovation and policy measures along, at least, four broad categories: (1) the energy supply side , (2) Energy demand and utilization, and related values, (3) Infrastructures, and (4) Multi-level governance. We believe that the role of infrastructures is an overlooked dimension of transition and innovation studies. Infrastructure is often thought of as a planning problem even though infrastructure transformations most often require major innovations (institutional and technological) to be realized. In this paper we will focus on the nature of infrastructure transformations (electricity grid) and its role in building low-carbon innovation systems (new RET).

Keywords
Low-carbon transition; infrastructure; innovation systems; electricity transmission.

1 INTRODUCTION 3

2 INFRASTRUCTURE AND INNOVATION 5

2.1 CHARACTERISTICS OF INFRASTRUCTURES: TOWARDS A DEFINITION 5
2.2 DYNAMICS OF INFRASTRUCTURES 9
2.3 INFRASTRUCTURES AND INNOVATION 12
2.4 INFRASTRUCTURES AND INNOVATION-SYSTEM TRANSFORMATION/BUILDING 13

3 TOWARDS ELECTRICITY SYSTEMS 14

3.1 TRANSMISSION THEN AND NOW 14
3.2 OPERATIONALIZATION OF FRAMEWORK 16

4 HISTORICAL DEVELOPMENT OF NORWAY'S ELECTRICITY GRID 18

4.1 THE FIRST FORMATIVE PERIOD: LOCAL NETWORKS 18
4.2 THE SECOND FORMATIVE PERIOD: REGIONAL NETWORKS 20
4.3 THE THIRD FORMATIVE PERIOD: NATIONAL NETWORK 21
4.4 THE FOURTH FORMATION: THE NORDIC NETWORK 22

5 PRELIMINARY REFLECTIONS 25

5.1 WIDER IMPLICATIONS 26

6 REFERENCES 27

2

1 Introduction

A transition to a low-carbon society involves innovation and policy measures along, at least, four broad categories: (1) *the energy supply side* which involves efficiency in fossil fuels (short term)[1], large-scale diffusion of (mature) renewable energy technologies (RET) to gradually replace carbon energy (creative destruction and overcoming carbon lock-in) and satisfy the growing global energy demand (short-medium term), and development of radically new sources of energy (needed for the longer term). (2) *Energy demand and utilization, and related values* imply changing high-carbon routines (travel, heating, electrical equipment, etc.). The latter can in the words of Pasinetti (1993) also be described as (green) user learning. It serves to limit demand growth and increase energy efficiency in household consumption and industrial use. It is furthermore central to creating democratic legitimacy for the nation states to engage in costly supply side policies. (3) *Infrastructures* are central to our high-carbon societies (Jonsson, 2000) and must, as the underlying structure, be transformed to facilitate supply and demand side changes. It concerns physical network systems such as transport and logistics (including air and space), water provision and management, energy grids, waste management and recycling, and housing (city planning). Electricity infrastructure (grids) is particularly relevant for renewable energy due to its geographical dispersion and intermittency which imply that renewable energy sources must be connected (and eventually stored) across sufficiently large territories to constitute a credible alternative to carbon energy. (4) *Multi-level governance* (local to global - 'Glocal') is a crucial. The former three dimensions require incremental and radical forms of institutional, technological and organizational innovations that require various forms of policy support, and all three must be addressed in a systemic and coordinated way at a global scale to achieve a low-carbon transition. Here radical institutional innovation is needed.

The four broad analytical categories help us to think about what is involved in a transition in a structured way. It helps us to see that the dimensions are mutually interdependent wherefore a systems approach is needed. The creation, diffusion and use of low-carbon knowledge (connecting the four categories) can be conceptualized as building low-carbon innovation systems and transforming existing systems of innovation towards low-carbon. All four categories will be represented in any IS analysis with varying focus, though. Even though we are only beginning to grasp the challenges involved in in a low-carbon transition we can identify certain patterns in research on the innovation aspects of a low-carbon transition. Most research (in innovation studies) focuses on the supply side (how renewable energy technologies develop, and lock-in) while acknowledging the demand-side. We believe that the role of infrastructures is an overlooked dimension of transition and innovation studies. Infrastructure is often thought of as a planning problem even though infrastructure transformations most often require major innovations (institutional and technological) to be

1 Would involve e.g. carbon capture and storage technology and 'clean coal'.

realized. In this paper we will focus on the nature of infrastructure transformations (electricity grid) and its role in building low-carbon innovation systems (new RET).

More concretely, it has been argued that the lack of offshore electricity transmission grid in the North Sea (and credible plans for establishing it) is blocking private investments in offshore wind capacity. In this sense, the fact that infrastructure is not changing constitutes a barrier for further developing the offshore wind innovation system in the North Sea. The latter is one case of a more general phenomenon of a global need for low-carbon transmission grids to facilitate development and diffusion of renewable energy (Tawney, Bell, & Ziegle, 2011). The latter makes up our main motivation for exploring how we can understand infrastructure transformation (internal innovation dynamics), and its influence on 'external' innovation dynamics (the economy more widely). In particular we are interested in the challenges involved in transforming and/or expanding electricity transmission grids to facilitate new sources of energy.

The paper is conceptually explorative which leads to into preliminary theory building. Furthermore, the paper is also empirically explorative because it seeks to illuminate the situation of stagnation in Norwegian electricity markets during the latest decade and to assess the feasibility of further studies and what these may look like (Hart, 1999). The purpose of this paper is thus twofold. First, we want to arrive at a conceptualization of infrastructure and its role in low-carbon transitions. Such an exercise, we hope, can contribute to research both on innovation system dynamics and transitions. Second, we want to empirically explore what can be learned from Norway's history of electricity infrastructure transformations with relevance for Norway's current situation.

As our empirical material we will look at the historical development of the electricity grid in Norway. We will look at the internal dynamics of its expansion to get a grip on the related innovation activities and technological developments. We will also look at how the changing electricity grid interacted with the transformation of other parts of the economy with focus on innovation. As conclusion we hope to be able to point areas in need of further research within this area and pose some concrete research questions for further work[2].

Section 2 will develop a conceptual framework for grasping infrastructure dynamics in relation to innovation activities. Section 3 will apply the general insights from section 2 and

2 A later paper will seek to empirically apply our conceptual framework on the Norwegian and the North Sea context with the purpose of diagnosing the current situation focusing on the role of infrastructure in the development and diffusion of RET. We believe that this first paper on conceptualizing the role of infrastructures must be prior to our contemporary empirical analysis where a first and main question must be "are there at all any problems with respect to electricity transmission infrastructure and investment in RET in Norway?" Hence, the intention will be posing the questions and framing potential problems about a concrete infrastructure (electricity transmission) in a specific context (Norway) at a specific point in time (now).

apply them to the electricity power system. Section 4 will contain our empirical analysis of Norway. Section 5 is the conclusion.

2 Infrastructure and innovation

We will focus on aspects of infrastructure that relate to challenges of transforming it. Our empirical focus will be on electricity infrastructure.

Infrastructures are the technical systems in society that distribute specialized services, materials and assets to households, companies and other organizations by supplying inter alia clean water, energy for heating and lighting, internet, telephone services, transport of people and goods . The development and expansion of infrastructures has been inherent to industrial development and thus facilitate the high levels of consumption, travel and energy use we can identify in OECD countries. These infrastructures were not designed to be sustainable but, in the words of Jonsson (2000), to be cheap, convenient and reliable in the quest for economic growth. From a (low-carbon) transition perspective this implies the infrastructures play a central role for achieving some sort of sustainable development.

2.1 Characteristics of infrastructures: towards a definition

According to Schipper & Schot (2011) the term infrastructure first appeared in 1875 in a report about a French railway project. Infrastructure referred to the 'understructure' of railways (land, embankments, and bridges) in contrast to their 'superstructure' (rails, stations, and any type of overhead structures). The term wasn't much used at first but rose slightly in popularity around 1950 in discussions of military defenses in England. It was used to describe airfields and air navigational aids that were understood as the 'material backing to enable the higher command to function and forces to be deployed'. The use of the term increased significantly as it became a cornerstone of the vocabulary of national and international development planners in the 1960s. In this context the term referred to more than 'material network technologies' by including 'social infrastructures' as the education system. The genesis of the concept reflects what is today commonly understood by it. That it refers to material structures, mostly large-scale, that support vital societal functions.

This understanding is also visible in popular definitions in social science. The Oxford dictionary of Economics defines infrastructure as "the capital equipment used to produce publicly available services, including transport and telecommunications, and gas, electricity, and water supplies. These provide an essential background for other economic activities in modern economies; the fact that they are not available or reliable is characteristic of less developed countries, and handicaps their development. Infrastructure services are generally either provided or regulated by the state." The Oxford English dictionary defines it as: "the basic physical and organizational structures and facilities (e.g. buildings, roads, power supplies) needed for the operation of a society or enterprise”. Still, it is a very broad term which complicates research. It is rarely meaningful to talk about infrastructure in general and its importance for economic growth because it is very complicated to trace the causal links between two such extremely abstract and broad terms both empirically and conceptually. Thus, a more precise and operationalizable definition is needed.

There are several approaches to studying infrastructure. According to Markard (2011) an engineering or technological approach has traditionally been dominant even though it is becoming increasingly interdisciplinary. Focus here is on ‘technical efficiency’ of a given infrastructure in the interactions and compatability between system parts or the development and implementation of new technologies. The technical dimension of the system notion is emphasized by Jonsson (2000) who defines infrastructure as consisting of links (grids) and nodes (power stations), and of flows passing through (electricity). Often nodes process the flows for the next node in the network. A different and dominant approach to infrastructure is the ‘regulation perspective’ where focus is on improving ‘economic efficiency’ of a given infrastructure service provision seen as natural monopolies (e.g. market liberalization and competition) (Markard, 2011). Still, to understand how such infrasystems emerge and transform (dynamics) it is insufficient to understand it as simply a set of technical components. Jonsson (2000) argues that infrasystem analysis must also include the organizations and people that use, build and operate the system, and the economic and legal conditions for the activities. Moreover, since infrastructure is defined by, erected and reproduced due to its social functions, it must be understood as a socio-technical system (Jonsson, 2000). We know from innovation studies that technological systems have important social dimensions and that ‘optimization’ approaches (both technical and economical) are essentially static. It therefore makes sense to move towards an evolutionary systems approach. According to Schipper & Schot (2011) historians of technology have studied infrastructure as ‘large technical systems’ in the tradition of Thomas Hughes (1983). Such systems tend to be large, complex and socio-technical.

Smith (2005) identifies a range of economic properties of infrastructure with implications for how they can be changed. Infrastructure is in general characterized by **Indivisibility**: it must be constructed as a system or a set of complemenbtary systems. **Multi-user**: because it is a general service, only one provider – one road system - is needed. The multiuser feature also imply that infrastructure most often is subject to **network externalities** (individual value rises with more users). This on the other hand imply that infrastructures tend to be very large systems. Indivisibility and the multiuser property imply that infrastructure investments often are significant larger than other types of industrial investments – they are **capital intensive** systems. Due to the combination of size and indivisibility, infrastructure is subject to **increasing returns to scale** which leads to formation of **natural monopolies**. Moreover, infrastructure is **generic** in the sense of being **overhead capital** which is defined as being available to anyone and not linked to anyparticular part of production. It is most often provided by governments, examples are roads, public parks etc. (Black, Hashimzade, & Myles, 2002). Smith (2005: 26) further suggest that many parts of infrastructure can be considered a **quasi-public good** that are nonrival and nonexcludable by their potentially large **positive externalities** for the rest of the economy (productivity spillovers). Lastly, infrastructure is also subject to very long life times (**asset durability**). The roads built by the romans are still in use and in many cities water and sewage systems are a century old. This implies that infrastructure generate stability and path dependency in both positive and negative ways.

We can add to these characteristics what Markard (2011: 12) calls 'systemness' which is high "*if there are strong complementarities among system components, which means that they cannot function without each other and overall system performance is highly dependent on how well the various components are coordinated*". Such interdependency/complementarity demands that if one element is changed, other elements have to adapt subsequently. This is true among different types of infrastructures, which we can call *internal systemness*, and between infrastructures and 'superstructures' (other parts of economy), which we can call *external systemness*. High degree of systemness translates into rigidity because to achieve change you need to adapt large parts the economy which can be very costly and difficult[3]. Along these lines, energy infrastructure is the most fundamental type of infrastructure, see figure 1.

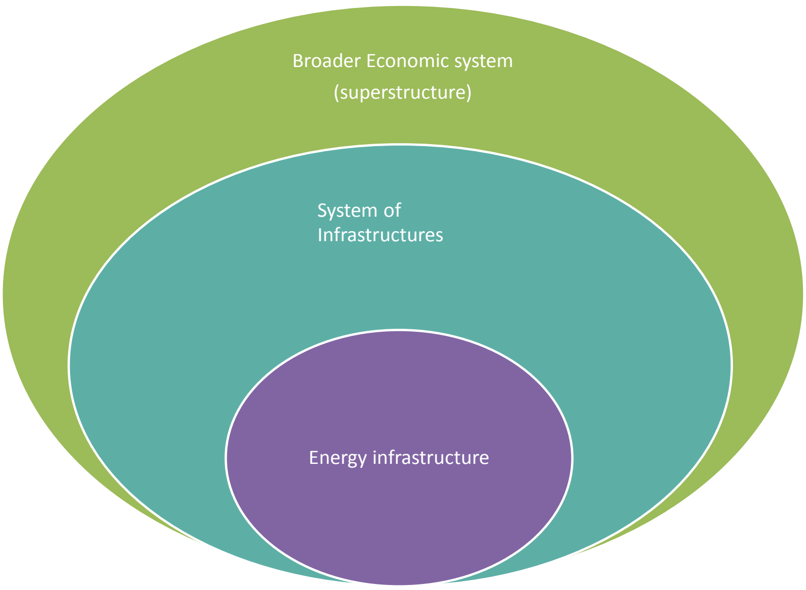

Figure 1: systemness and levels

[3] One analogy is to imagine completely transforming the ground floor, fundamental to the rest of the building, in a 30-storage building.

7

Due to indivisibility, large scale, capital-intensity, externalities, systemness and long time time horizons infrastructure investments are associated with large uncertainties that often deter private investors. Moreover, the centrality of infrastructure to the functioning of society entails that they are of strategic importance and often a matter of national security. As a consequence, infrastructure has historically been provided by governments rather than private actors (though many types of regulation and public-private partnerships can be observed). Governments are, in contrast to private companies, well-predisponed to take on infrastructure development due to their unique organizational capabilities to cope with uncertainty (socialize risk), to mobilize large resources (human and financial), and thus carry out large-scale investment projects, and to explore a range of different innovation paths (Smith, 2005).

Markard (2011) translates these properties of infrastructure into an dynamic analysis with the objective of understanding the transformation of infrastructures[4]. He concludes that the identified features of infrastructure imply that "*infrastructures typically evolve gradually and with only incremental changes along established paths*" and thus pose barriers to fundamental transformation of infrastructures and thus society at large. Infrastructures are thus reasonably different from other sectors of the economy (that are also characterized by resistance to change; qwerty-type lock-in) and (even more) resistant to fundamental change.

On the basis of the literature reviewed above we define infrastructure as a *physical network of fundamental importance to the functioning of society (superstructure). It consists of technologies, actors, and institutions to make up a socio-technical system. It is characterized by indivisibility, large scale, capital-intensity, externalities, systemness and asset durability that imply that lock-in is stronger than other parts of the economy, that change is dominantly incremental and that public regulation and/or the government most often plays a strong role*[5][6].

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[4] His nuanced treatment of regulation is conceptually divided intro analytical categories of regulation type/intensity, role of public organizations and competition intensity.

[5] The regulative challenge sometimes creates further rigidities due to the level of risks involved on behalf of any potential investor. This risk often makes governments negotiate long-term contracts (20-30 years) with investors in order to secure their commitment (that they don't bail out). It has the derived consequence that governments are unable to change or cancel an infrastructure projects that are already launched even if circumstances change against its profitability. Such contracting practice has produced perverse situations where obviously obsolete infrastructure projects go ahead and are left stranded. Often mentioned factors behind lock-in are technical interrelatedness, economies of scale, and quasi-irreversible investments (QWERTY). As such infrastructures are subject to further institutional lock-in factors in form of rigid contracting (Walker, 2000).

[6] Walz (2007) argues that electricity systems suffer from further rigidities that other infrastructure sectors with respect to transformation. He argues that the electricity sector is faced with some unique regulatory challenges due to the type of dominant actors. Due to the strategic importance of energy for national security, sunk costs and natural monopoly, energy sectors are highly regulated. This can take many different forms but public utilities are most often the dominant actors. They have as their primary mission to balance demand and supply of electricity and stabilize the grid. This often creates disincentives to integrate intermittent renewables at large scales. In most countries public utilities control the grid even though electricity generation has been liberalized. The expansion of renewable energy is crucially dependent on access to the grid. Public utilities can thus indirectly via grid transformation control strongly influence the cost-competitiveness of renewable energy. In cases where utilities are also generating electricity, they are in direct competition with the new emerging

In the innovation studies tradition infrastructure, to the extent it has been analyzed, has been understood primarily as intangible knowledge assets or the systems that generate such knowledge bases. We do not find this approach fruitful, see text box.

Infrastructure versus innovation systems
Within innovation and technology studies the term infrastructure has been used even though not widely. Given the disciplin's focus, infrastructure (the fundament for society's prosperity) is 'naturally' argued to be knowledge and technology – as e.g. 'technology infrastructure[7]' (Tassey, 1991), 'infrastructure for entrepreneurship[8]' (Ven, 1993), 'knowledge infrastructure[9]' (Smith, 2005), and 'soft infrastructure[10]' (Cooke, Uranga, & Etxebarria, 1998). We agree that knowledge production has infrastructural characteristics and that it can be seen as fundamental to long term prosperity of nations and firms. Still, we are entirely convinced that broadening the term infrastructure to encompass institutions, social capital, technology centers, science system, labor markets and even industrial structure is a fruitful way to conceptualize infrastructure. All the mentioned factors are important for innovation activities and entrepreneurship, but that does not make them infrastructure. Instead, these broad all-encompassing notions of infrastructure are much closer to what is normally understood with a system of innovation which consists of "the elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge" (Lundvall, 1992). The structural elements of an IS are often categorized as institutions, actors, networks and infrastructure This is especially true for geographical delimited ones as national and regional IS that are anchored in a physical basis. The point here is that the IS concept contain a richness of analytical concepts that in principle would be lost be calling it all plain 'infrastructure'. The latter would also limit our possibilities for analyzing the interactions between institutions, entrepreneurship, universities, technological change and (physical) infrastructure[11]. Moreover, since the latter is exactly our empirical interest, we will not apply the infrastructure terms discussed above.

2.2 Dynamics of infrastructures

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producers that obviously are largely overmatched in terms of resources and power. In terms of competition, a level playing field is not in sight.

7 The technology infrastructure consists of science, engineering, and technical knowledge available to private industry. Such knowledge can be embodied in human, institutional, and facility forms. More specifically, technology infrastructure includes generic technologies, infratechnologies, technical information, and research and test facilities, as well as less technically-explicit areas including information relevant for strategic planning and market development, forums for joint industry-government planning and collaboration, and assignment of intellectual property rights.

8 It includes: (1) institutional arrangements to legitimate, regulate, and standardize a new technology, (2) public resource endowments of basic scientific knowledge, financing mechanisms, and a pool of competent labor, as well as (3) proprietary R&D, manufacturing, marketing, and distribution functions by private entrepreneurial firms to commercialize the innovation for profit.

9 Defined as universities, research labs, training systems, organizations related to standardization and intellectual property rights protection, libraries and databases. This makes up a stable framework of collective inputs including scientific and technological activities and institutions which private industry uses. Knowledge infrastructure is an important part of systems of innovation it is argued.

10 Soft infrastructure is defined as the social infrastructure of solidarity, civic engagement, reciprocity, and trustfulness that is the basis for collective action in many dimensions, including the formal policy dimension. The authors also include knowledge infrastructure, as defined by (Smith, 2005). It is opposed to hard infrastructure as telecommunications and transportation.

11 This discussion relates to whether infrastructure (both tangible and intangible) should be seen as external or partly internal to an IS.

From the previous section we know that are characterized by high rigidity towards change, and that change therefore most often is incremental rather than disruptive. Thinking further about the dynamics of infrastructure we come to grasp its inherent duality as both a static and a dynamic structure.

Infrastructure systems intuitively appear as a fixed structure which makes us think of it in a static way where the most important public concerns are its daily functioning and to optimize cost-efficiency in a 'closed' technical system. As soon as we try to understand how such system change, it becomes obvious that they are socio-technical systems that are continuously maintained/reproduced and transformed, and that these processes are supported by a system of knowledge bases. Hence, we may think of infrastructures as *static systems in the short-run* but as *dynamic systems in the long-run*. As argued by Ridley, Yee-Cheong, & Juma (2006) one consequence of this distinction becomes obvious when thinking about infrastructure policies. Many African countries try to achieve economic growth via building infrastructure financed by foreign direct investment. The common practice is to focus on the financial part of the infrastructure project rather than on the technological. The authors argue that infrastructure should be understood as technological learning projects that must be locally anchored in terms of capability building, and thus integrate infrastructure projects into the broader competence development strategy rather than understanding infrastructure as something static that should be bought.

Regarding infrastructure dynamics Kaijser (2005) distinguishes between internal and external dynamics. In our perspective *internal dynamics* refer to 'structural tensions' emerging from the interaction between the components within the infrastructure itself. *External dynamics* refer to how, for various reasons, transformation pressures for change in infrastructures accumulate externally (in superstructure) to a point where it is inevitable despite its inherent rigidity (from superstructure to infrastructure). External dynamics also include the influence a given infrastructure exercises on other economic sectors totally dependent on it (infrastructure to superstructure). Given infrastructure's inherent rigidity we expect that a significant volume of transformation pressure must accumulate in order to cause infrastructure transformation.

The latter point is developed further by Thue (1995) who introduces useful concepts for analyzing the Nordic energy systems. His analysis focuses on the interaction between technological and institutional change. His argument is that large technological systems go through *'open' and 'closed' periods* or can be characterized by open/closed situations. When the system is closed, there is little change to established system configuration[12]. When it is open, there is a so-called window of opportunity for change where institutional set-up is relaxed and new actors, technologies, and/or institutions emerge. We may call the open

[12] In closed periods, pricing is based on variable costs and not on covering the fixed cost of capital (re)investment.

situations *'transformative periods'*. The system opens as the result of external forces (both new technology (niches) and/or landscape pressures) which outweigh the electricity system's own dynamics and make room for change (Thue, 1995: 27). We can extend and generalize Thue's framework to say that due their inherent rigidity, infrastructure systems are dominantly 'closed' ('static' and characterized by incremental change) and only 'opens' and enters transformative periods when sufficiently strong transformation pressures have accumulated externally (leading to dynamics and disruptive change).

Our discussion of systemness (complementarity between components), transformation pressure and system dynamics leads us to the Swedish economist Erik Dahmén and his work on structural change which he sees as driven by positive (opportunity) or negative (necessity) *structural tensions*. The basic idea is that complementarity exists among technological, economical and related factors. These complementarities often produce bottlenecks or structural tensions. If e.g. a new field of technological opportunities arises which makes it profitable to restructure the economy, then transformation pressures will arise for new investments to be made. Once these complementary investments are in place, the development potential is released. When the complementary investments in turn produce further structural tensions in other parts of the economy such that industries interdependently develop over a longer period, then we can talk of a *development block*. A development block refers to a sequence of complementarities which by a way of a series of structural tensions (disequilibria), may result in a balanced situation or in a new structural tension (Dahmén, 1994). Structural tensions can emerge on micro, meso and macro level. The source of structural tensions is most often new knowledge and/or new market opportunities. Dahmén (1986) mentions the following events as sources of transformation pressure: (a) introduction of new methods of production and marketing; (b) appearance of new markets and marketable products and services; (c) exploitation of new sources of raw materials and energy; (d) scrapping of old methods of producing and marketing products and services; (e) disappearance of old products and services; (f) decline and fall of old markets; (g) closing of old sources of raw material and energy. Dahmén observed that different forms of complementarity exist between industries and firms, and that these connected actors can be seen as an 'organic' block whose components co-evolve as response to external or internal changes. With reference to our discussion above structural tensions can be generated internally from interaction between components or externally in the interaction between infrastructure and superstructure, see figure 2. We are now approaching a tentative model of infrastructure dynamics.

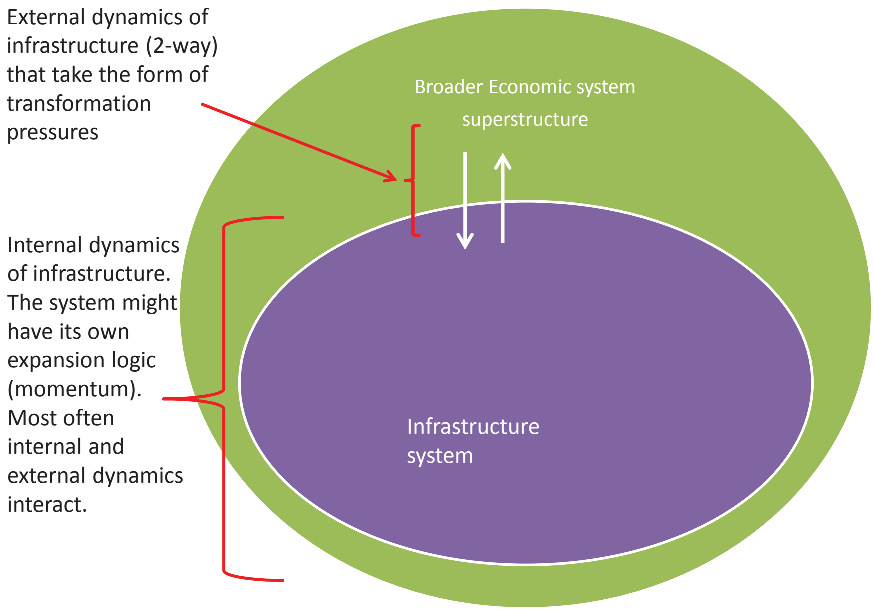

Figure 2: Internal and external structural tensions

2.3 Infrastructures and innovation

Even though it has been convincingly demonstrated that new technologies (notably 'radical' ones) are associated with and requires a specific infrastructure in order to emerge and diffuse (Freeman, 2001), infrastructure has received relatively (compared to terms as institutions, knowledge bases and organizations) scarce attention. Still, it is intuitively clear that it is difficult to really grasp how radical and/or large-scale technologies are developed, become established and are diffused without taking into account the role of infrastructures. The combustion engine for example needed roads and the telephone needed telephone lines to diffuse. Furthermore, provision of infrastructure directly affects which economic activities are competitive, and thus industrial structure, as e.g. the provision of hydropower in Norway is the primary reason for the country's aluminium industry (external dynamics). Smith (2005) argues that infrastructure is often neglected in innovation studies. Moreover, due its importance for technological change, innovation studies have a particular need for clarifying the concept of infrastructure. In the area there is frequent references to and use of the term inter alia in the form of institutional, knowledge, or entrepreneurship infrastructure. Still, most often it is unclear what is meant. According to Smith (2005: 19-20) "*infrastructure seems to be used as a kind of short-hand reference for a wide range of framework conditions, institutional setups, collective inputs, public utilities and so on". One implication is that the concept is applied in an inconsistent and unrigorous way*". There is thus a need for a more accurate conceptualization of infrastructure and how it relates to innovation system performance, building and transformation. This is true both for 'traditional' innovation-system analysis (Lundvall, 1992; Malerba, 2002; Nelson & Rosenberg, 1993) and the more

12

recent ‘functional approach’ (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008; Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007).

The inherent duality of infrastructure dynamics described above is also relevant for the links to innovation. On the one hand, due to the characteristics described above, infrastructures are difficult to change and predominantly change incrementally. This is implies that in the short run, infrastructures appear a static structure that is part of the landscape. As such it influences innovation activities just as other structural components of an innovation system e.g. institutions (part of selection environment for innovation). It refers to how a given infrastructure in a specific moment in time affects the direction of innovation activities by being more compatible with and conducive to some types of innovation over others. Furthermore, infrastructure facilitates the working of external innovation systems via its provision of crucial services, and thus serves as a basic underlying structure for numerous innovation activities throughout the economy. This can be described as the (outgoing) external innovation dynamics of infrastructure in the *short run* – how it influences innovation activities in other sectors of the economy.

On the other hand, infrastructures are most often large technological systems with internal innovation dynamics. The drivers of internal dynamics were described above. How they look like depends on the context and the maturity of the infrastructure. We can say that in the *longer run* infrastructures are best understood as (technological) innovation systems that are of fundamental importance to other sectors of the economy. Infrastructure is subject to innovation activities as it transforms according to the strength of prevailing transformation pressures at any given moment. When infrastructure is seen as an innovation system, its innovation dynamics are both internal and external.

In the short run infrastructures influence innovation as static structures affecting the direction of innovation activities – they are closed. In the longer run infrastructures must be understood as dynamic, open and conceptualized as systems of innovation. They open as a consequence of strong external transformation pressures. When they open, modifications in one part of the system will create disequilibrium and structural tensions in the whole system which requires further adaptation. This in turn generates a phenomenon similar to development block dynamics. When this happens, new institutions, technology and/or forms of organization are introduced to the infrastructure whereafter the system closes again and starts a process of static optimization via incremental innovations. In the longer run infrastructures and superstructures co-evolve.

2.4 Infrastructures and innovation-system transformation/building

The duality described above entails that when thinking in terms of innovation-system building and transformation we are inherently talking about system level interactions. Given the

13

fundamental character of infrastructure, part of it is inevitably part of nearly any imaginable innovation system (technological, sectoral, national, regional). Still, it is most often only noted when it blocks transformation and more rarely when it facilitates change. Hence, building new and transforming existing IS will most likely involve building new, dismantling and/or expanding existing infrastructures (obsolescing them)[13].

Infrastructure is a 'slow-moving' and rigid innovation system that blocks or facilitates the building and transformation of certain 'less-fundamental' types of innovation systems. In this sense the interaction between short-run versus long-run dynamics in infrastructures can be conceptualized as interaction between different types of innovation systems (an infrastructure system interacting with a production system).

3 Towards electricity systems

Electric power systems are generally divided into generation, transmission, and distribution of electrical energy (Tell, 2005). Sometimes utilization is also included. It refers to volume (quantity), energy efficiency (quality) and location of demand. In this paper we treat all as external to the electricity system. Hence, the internal dynamics concerns structural tensions/complementarities between generation, transmission and distribution[14]. We have argued that energy is the most central infrastructure (most systemness), not electricity. Still, electrification of heating and transport is expected to play a key role in a low-carbon transition, which gives some support to, for practical reasons, limiting ourselves to electricity infrastructure as the key infrastructure to transform.

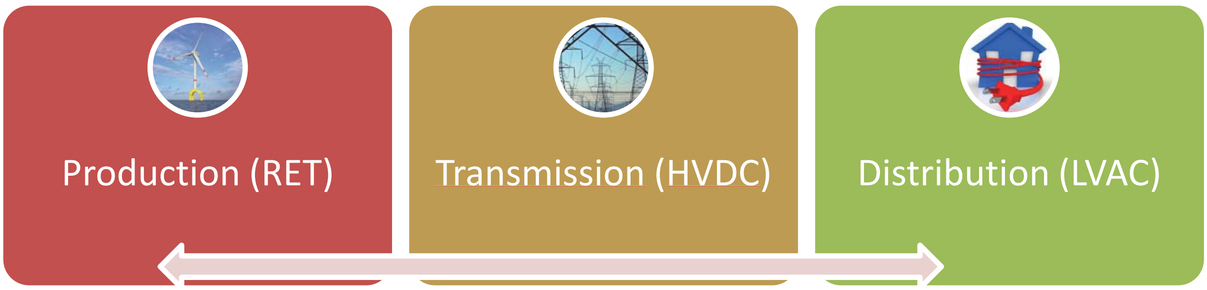

Figure 3: Internal components of electricity infrastructure and their interactions.

3.1 Transmission then and now

13 It is implicit that we understand the term innovation system as more than a heuristic focusing device and analytical concept. Systems of innovation can exist and that they are modifiable/transformable by agency even though the complexity involved often implies unintended results.

14 We mainly focus on the link between generation and transmission but from another perspective distribution and utilization are equally influential on grid developments. That part of the grid is most often referred to as 'smart grids' that, even though not subject to any widely-shared definition (Yuan & Hu, 2011), tends to focus less on transmission and geography of energy sources. Still, an analysis of the future 'super smart grid' would need to involve all these dimensions because systemic complementarities between them exist.

The history of electric power systems started with Thomas Edison's AC-based local lighting system and has gradually developed into large and complex infrastructures. Each expansion was characterized by system building in form of institutional, organizational and technological innovations. As local systems were up-scaled and demand increased, there was more need for long distance transmission. In fact the logic behind the developments of such systems is that energy generation can be located quite far from utilization (Tell, 2005).

Especially with the introduction of geographically distant power generation plants (notably hydro), a demand for more efficient long-distance transmission emerged. This caused a 'second battle of systems' between high-voltage AC and high-voltage DC (HVDC) transmission. The point being that when transmission voltage increased, transmission losses decreased. Despite a number of advantages HVDC still hasn't replaced AC as the dominant electricity transmission system worldwide even though several have been erected, see text box. Still, this may be about to change due to increasing introduction of renewable energy.

Due to geographical concentration of renewables (and public resistance to overhead cables), it seems that our future low-carbon transmission systems will mainly consist of underwater and underground cables (tidal, wave, offshore wind and solar [from Africa]).

Offshore wind will move further from shore and although wind power can be used locally, its large-scale use implies using large turbines located at sites with high wind speeds that are likely to be located relatively far from centers of demand. Furthermore, even though biomass can be produced and used locally, its large-scale application will (due to population concentrations in cities) involve transport either (i) as processed pellets in trucks or trains which can prove unsustainable, (ii) or in the form of electricity via a transmission grid. The above implies that transmission will increasingly be based on HVDC cables rather than HVAC overhead grids (Boyle, 2012). This constitutes an enormous future market, and a reason for looking into the industrial and technological aspects of new transmission systems. The costs involved are staggering. Though existing grids can be upgraded, new grids (expansions) are needed. According to Boyle (2012: 493), a 400kV AC line cable carrying 3 GW costs about 1.3 £ million per kilometer to construct while underground cables (HVDC) may cost up till £ 10 million per kilometer.

Advantages of HVDC:

- Can be used as underground and underwater cables instead of land lines, which make electricity less vulnerable to enemy airplanes. AC systems are subject to *reactive effects* which make it inappropriate for this.
- For transmission over long distances AC systems become instable due to inductance and capitance effects.
- Less cable/wire was needed for DC systems
- DC is more controllable. You can change direction of electricity in seconds while in AC systems such

changes can destabilize system. Implies that most cheap source of energy can be used instantaneously at all times. This leads to cost effectiveness.

- The economic properties of HVDC favors transmission distances over 500 km while with (HV) AC majority of transmission is accomplished within a range of 350 km. Converting between AC and DC has become increasingly cheaper via electronic interfaces (Farret & Simoes, 2006)

Disadvantages of HVDC:

- High cost for 'switching' (between AC and DC) substations (tranformers)
- Complicated technology requiring high maintenance and equipment cost (e.g. rectifiers).

IEA estimates that in order to replace fossil fuels with renewable energy in the period 2010 to 2050 to the extent that emissions are halved, the global investment need in transmission amounts to 4.2 trillion USD - equivalent to 100 billion USD a year. To put these figures into perspective, United States' 2009 investment in transmission was $9 billion (Tawney et al., 2011).

The American Wind Energy Association states the key issue in grid developments as "*a typical transmission line takes five years or more to be planned and built, while a renewable power plant can be constructed in less than a year. Transmission developers are hesitant to build transmission to a region without certainty that a power plant will be built to use the line, just as wind and solar developers are hesitant to build a power plant without certainty that a transmission line will be built*" (Tawney et al., 2011). Based on analysis of infrastructure transformations in history, Kaijser (2005) argues that transformation (or establishment) of infrastructures "*has often been dependent on a crucial institutional innovation, which made it possible to overcome the initial uncertainty by distributing the huge capital costs for building facilities and networks among many users*".

It seems reasonable to conclude that infrastructure transformation most likely need to be preceded by institutional innovation that can facilitate resource mobilization. Still, the sources of transformation pressure for engineering such institutional change are not addressed by Kaijser. It most likely arises from shifting power relations among advocacy coalitions (networks) that compete for social legitimacy and different visions about the future. As mentioned earlier such advocacy coalitions can take the form of industry lobbies, citizen movements or political visions[15].

3.2 Operationalization of framework

15 The mega trend in electricity power systems across OECD countries over the last two decades has been deregulation (privatizations and competition). It is an open and empirical question how the latter trend, which in some cases has increased efficiency (Hammons, 2008) and (incremental) innovation (Markard & Truffer, 2006), has affected the sector's transformation capacity – to do 'system innovation' rather than efficiency within-trajectory innovation which is involved in changing transmission grids.

16

The figure below gives us a static understanding of how electricity infrastructure is coupled to other infrastructure sectors, and how all of them are coupled to the wider economic system. Still, we need to move towards a dynamic understanding on the basis of insights above.

Due to the historical development of electricity systems it makes sense to conceptualize their transformation as taking places in successive transformative periods where the system is ‘open’ to change as a consequence of accumulating transformation pressures. In between these ‘open’ situations, the system is ‘closed’, fairly stable and characterized by incremental, if any, changes due to its inherent rigidities. In such a ‘closed’ situation, transformation pressure emerges externally, and if it becomes sufficiently powerful (vis-à-vis other advocacy coalitions and institutions), the system will ‘open’ again.

Our empirical point of departure is the coupling between the absence of transmission infrastructure to facilitate investments in various types of renewable energy in Norway. There are currently transformation pressures for introducing new renewable sources of energy in Norway’s electricity system with the purpose of exporting it. That is external transformation pressure on the energy infrastructure to change. The pressure on the generation dimension of electricity infrastructure generates internal structural tensions for change due to the complementarity between the dimensions. In the current situation changes in infrastructure are required in order to stimulate the building of several renewable energy technological innovation systems. Our empirical task of analyzing the historical transformative periods of transmission infrastructure in Norway becomes to identify the sources of transformation pressures that eventually led to opening up the system, and understand what type of institutional, organizational and technological innovation was involved. Given the historically important role of government in changing infrastructure, we also enquire into what the role of government and policy has been.

Table 1: analytical focal points for empirical analysis

	Period 1	Period 2	Period 3	Period 4
Why change? What were the sources of transformation pressure. Internal or external? Need / opportunity? All dimensions of electricity infrastructure affected equally?				
Related technological, institutional and organizational change? (innovation)				
The role of policy / the state				
How were resources mobilized / investment needs met				
The main actors				

17

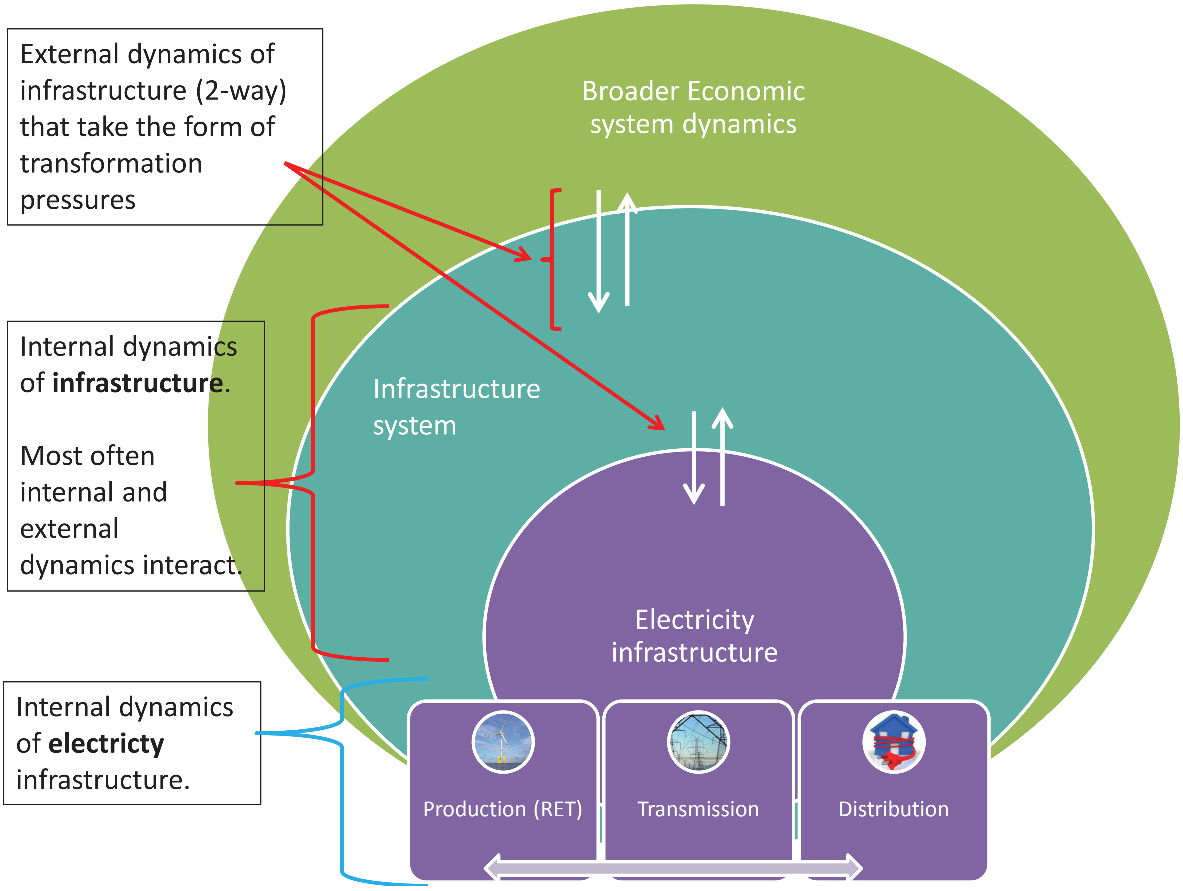

Figure 4: The multi-level dynamics of electricity infrastructure.

4 Historical development of Norway's electricity grid

In this part of the paper we will present some stylized facts regarding historical periods characterized by change or transformation of the infrastructure of the electricity system in Norway. We draw on empirical work by historians of electricity (Nilsen & Thue, 2006; Skjold, 2006, 2007, 2009; L Thue, 1995; Lars Thue, 1995) . Lars Thue (1995) argues that the Norwegian electricity system today may be seen as the outcome of four 'formative periods'. The focus of the presentation is on how the electricity system first emerged, and how 'barriers to change' for infrastructure transformation (Smith 2005, Markard 2011) were overcome or how it blocked further development.

4.1 The first formative period: local networks

The first formative period was characterized by development of hydropower stations producing for local users, most often a company. The electricity was mainly used for light in factories/ production units, and later also as power for machines. This type of electricity systems emerged from the late 1870s, and by 1890 there were at least 77 electricity units in operation. In 1889 there were 59 electrical power systems for lighting in companies in Norway. The numbers of companies producing electricity for own use increased rapidly during the late 1890s, and by 1900 there are registered 629 local electricity systems of this type. At this time more than 10 per cent of companies using any form of mechanical power had established a local electricity system (Wale, 2004; 250-251).

After the turn of the century the trend of creating separate power stations for industrial units took a new turn, involving the establishment of large scale electrical systems linked to electrometallurgical and electrochemical industries. The new factories were located near the power stations in order to reduce loss of energy through transmission over longer distances. New small towns were constructed around the power station – industry factory in Rjukan and Notodden (Norsk Hydro), Odda, Sauda. This created a demand for short distance grids, but not for long distance transmission as each power station was connected to one local user. The power station and the use of electricity were physically integrated.

The first phase of electrification of Norway was therefore characterised by firms investing in local power stations for their own use, both relatively small scale and large scale power systems. However, only a relatively small numbers of companies got access to electrical power through this system by 1905. Most small companies, farmers and other sectors of the economy remained without supply of electrical power. This created a political reaction were many local municipalities decided to build a small-scale power station to supply consumers, farms, and small scale industries with electricity. This expansion was particularly rapid during WWI.

The outcome of the first formative phase of electricity was therefore a *dualistic system* of local power supply units, providing power for a) (relatively large) individual companies or b) for local communities and small producers. The first part of the wider system was based on commercial decisions, the latter based on political initiatives. The demand for grid was limited to local distribution within limited geographical areas, most often within the same municipality.

Most of the large-scale electro-intensive industry investments were based on foreign capital. The strong role of foreign investors in large scale electricity investments created a reaction from Norwegian politicians. Lars Thue argues that the government used national electricity board (NVE) as in instrument to realize a broad set of political objectives. “The Norwegian electricity regime has without doubt been the one [of the Nordic countries] most dominated by politics” (Thue 1995: 25).The politicised electricity regime is studied as a reaction to the weak direct control of the state in its early formative phase. In contrast to Sweden and Finland the Norwegian state had very little direct control of the hydropower production stations during this period. The state/ political system therefore introduced strict indirect mechanisms to

19

regulate the electricity regime which to a large extent was controlled by large international industrial and capital organisations, and to a less degree by local authorities/municipalities. The limited involvement of NVE in electricity production contributed to a stronger need for laws regulating private industry. (Thue 1995: 26)

In this period investment in and expansion of the electricity system was initited due to external transformation pressures emerging from firstly industrial needs (lighting and manufacturing operations) and secondly from social/distributive policies aiming at supplying small firms, farms and citizens with electricity. Both developments involved organizational innovations in the form of integrated power-production sites and municipality-organized power stations. Consumption was local so there was no need for transmission. It furthermore involved implementation and diffusion of hydro-power technology. The weak role of the State in these matters resulted in a particular regulation regime (institutional innovation).

4.2 The second formative period: regional networks

In the interwar period demand for electricity fell below supply, investment in new power stations became insignificant, and total power production stagnated. This change in demand created an imbalance in the established power system. Many local power producers experienced long periods of surplus electricity. Local user(s) could not any longer use the total volume of electricity generated in the local hydropower station. Electro-intensive industries experienced lower demand and strong competition on international markets, and reduced production of metals and chemicals. Power stations started to search for new consumers. Growing demand in larger urban centres became important for the transformation of the system. In the larger cities a consumer market for more electricity emerged as electrical heaters and cookers became more common. Construction of transmission system from established large scale power stations to urban areas became the basis for extending the electricity systems into larger regional systems. The main example is how the fall in demand for industrial electrical power in Rjukan and the lack of supply in the Oslo region resulted into investment in the construction of a transmission line between Rjukan and Oslo/Skien. The cable contributed to the development of a regional electricity system in (part of) Eastern Norway, which made the existing production capacity more efficient and improved the cost-efficiency of the power sector.

In addition to the emerging urban consumer market, demand for electricity also increased in some rural areas due to rapid expansion of new small-scale manufacturing producers (Sejersted 1982). Small electrical motors and new organizational methods were introduced. The economic social crises resulted in reduced salaries, and the combination of new technologies and lower costs created radically lowered prices of a number of consumer products. It was therefore an industrial strategy behind the electricity development: a support for local and small scale industrialization by providing cheap electricity to various types of producers. It particularly strengthened small scale and rural industrial development.

The transformation of local energy producers into a regional electricity system involved wider change of the power system. The local electricity producers entered into collaboration and cooperation to develop large scale hydropower projects and grids, and they became relative stronger actors in the system. The trend towards horizontal integration strengthened the local consumer- and distributor oriented utilities into regional networks and suppliers. Norway became the first Nordic country to develop regional electricity markets in the early 20th century. This demanded technological innovations in grid technology, particularly introduction of cables with higher voltage. In the interconnected Oslo region cables with a voltage of up to c. 130 kV were introduced, and by 1950 the voltage in the regional grid increased to 220 kV

Again a structural tension between supply and demand of electricity generated transformation pressures on the electricity system. Due to external changes, the volume and geography of demand for electricity changed, and this created a need for transmission (internal adaption)[16] and transformed the system from local to regional systems. These changes again involved new forms of organization, new institutions (regulation) and new technology (transmission and large-scale hydropower).

4.3 The third formative period: national network

During the 'third formative period' following the end of WWII the state's direct involvement radically changed the electricity system. During the long period dominated by Labour Governments 1945-1965 an industrial modernization policy where large scale electro-intensive plants (demand) constituted the core of the strategy was introduced. As part of this industrial policy large hydropower stations (supply) were constructed and national transmission systems developed (infrastructure). Most of the investments were undertaken by the state which from now controlled directly both production and distribution networks for electricity. This secured abundant and cheap electricity to industrial users, but also relatively cheap electricity to households. The electro-intensive industries were partly owned by the state or by foreign companies. The state strengthened its control over the power system, and the control was even stronger from the 1960s when environmental issues entered national policy.

A number of large scale power stations were built, and total consumption increased dramatically. In 1946-47 the total consumption was c. 10TWh , in 1956 20 TWh, 1965 42 TWh, and in 1973 61 TWh. The industry became a dominant user, consuming more than half

[16] Transmission is inherently linked to urbanization it seems.

21

of all power (SSB, 1978; 145). The rapid expansion of large power stations and large scale electro intensive industries in many parts of Norway (Årdal, Sunndal, Høyanger, Årdal, Odda, Sauda, Lista, Kristiansand, Rjukan, Notodden, Mosjøen) in addition to increased demand fror larger urban regions, resulted in pressure on the emerging national transmission system. New management systems and regulations were introduced to increase energy efficiency and security (institutional changes). Regional systems became closer integrated into a national grid (exchange of power between regions, "Samkjøring") to improve energy security and improve overall efficiency of the system. This created demand for investments in the transmission system. Energy security was also the main argument to build cables linking the Norwegian hydropower system to the Danish heat based system, as well as the Swedish combined hydropower and nuclear system. (Skiold 2006: 141-2)

From the 1970s a new industrial strategy became dominant in Norway. This was linked to the build-up of offshore oil and gas sector. From a power perspective we may argue that this introduced a type of electricity production of the same type as observed in the very early period of the history of electricity: local power systems. Oil companies produced electricity for own consumption on platforms using gas turbines. The total production of local systems grew to more than 10 per cent of total national power consumption. The local electricity production was due to location far away from existing grids and there therefore very high costs involved in constructing transmission lines from hydropower based power.

In this period the State was the main source of change (representing industrial interests). Its industrial policy co-coordinated growing industrial electricity demand, expansion of electricity production, and the establishment of a national transmission system. Again transformation pressures arose externally to transform the system. Institutional changes (security and efficiency) further generated transformation pressures for establishing international transmission lines. The emergence of the oil industry and its use of electricity created a new de-centralized branch of the electricity system. Technological changes included further upgrading and up-scaling of hydro-power and transmission, and the integration of gas turbines.

4.4 The fourth formation: the Nordic network

The 'fourth formative period' took place with the liberalisation of the electricity markets in the Nordic countries from the early 1990s. Norway started this process as a reaction to consequences of the centrally planned and controlled system established during the post WWII period. High level of investments in hydropower production created a period of abundance of power in the late 1980s. The state and local municipalities continued to dominate the power system. Statkraft remained the largest producer of electricity (30% of total output) and most of the remaining electricity plants are controlled by local authorities/municipalities. Statnett became the dominating company in distribution on

22

regional transmission nets, and has monopoly to build international transmission cables/networks.

A new Energy law was introduced in 1991. The main change in the system was that electricity became transformed into a commercial product were supply and demand decided prices. As there was a surplus of electricity during the early 1990s and the demand for electricity stagnated, prices remained low until c. 2003. The implication was a long term gradual and incremental improvement of the electricity system, where the involved electricity producers and grid owners gradually made the system more efficient. However, the stable and efficient system was stagnant. There was hardly any investment in new power capacity until the mid-2000s. During the same period also investments in transmission remained insignificant. There were some exceptions, mainly the construction of links between Norway and neighbouring markets in Sweden, Denmark, Germany and the Netherlands. This was undertaken to improve energy security.

For the first time in Norway’s electricity history there was no link between the electricity system and industrialisation or industrial strategies. The power system was not any longer an infrastructure for wider industrial development. The electro-intensive industries entered into a commercial relationship with power providers: they became costumers procuring power on a commercial basis.

In this period international, institutional changes in the form of ‘neoliberal’ ideas, and over-production of electricity generated transformation pressure on the regulation regime of the electricity system. Regulation was changed towards competitive/perfect markets and market efficiency. These institutional changes have ensured stability, stagnation (production and demand) and low prices.

23

Table 2: overview of empirical analysis.

	Period 1 (1906-1917): Local networks	**Period 2: 1927-32: Regional networks**	**Period 3: 1950-1960: National networks**	**Period 4: 1991-1996: Nordic networks**
Drivers for change/ pressure for transformation **Dimensions of electricity system affected?**	Large scale industrialization, opportunity to exploit hydro-power. Small scale local/ municipalities power stations: support local industry	Reduced el demand from large scale industry; pressure due to imbalance demand – supply. Small scale industrial dynamics increased demand. Limited effect on production; most on transmission and distribution.	Policy driven large scale industrialization. (State owned and MNC).Opportunity. All aspects of el system affected: production, transmission, distribution + users (industry)	Surplus supply: political aim to re-establish balance. Delinking industrial policy from electricity policy. (Oil new industrial strategy). Little/no investment in transmission; some international links for energy security and balancing market.
Related change: technological, institutional, organizational (innovation)	Limited/no transmission technology. New industrial and hydropower technology. Consession Laws. New organizations: NVE, industrial companies, local authorities Technological organizations: STG, NEK, engineering companies, construction	Regional transmission system – 'samkjøring' Østland 1932. Institution: collaboration between local actors into regional groups (more large scale projects). Horizontal integration. Technology: 130KV, gradually increasing to 220kV in 1950. Some capital goods: cables, turbines (NEBB, Kværner, Myren, Per Kure) Hydropower laboratory Materials: concrete. Engineering/construction.	Long distance high tension transmission/transformer (incl sub sea). Institutional: state organizations become dominant; integration industrial and energy policy. Technological organizations: R&D, capital goods, engineering/ planning, materials Gradually strengthening state control	Institution: Electricity Law 1991; Nordpool 1996. Organisation: NVE divided in three (NVE, Statnett, Stakraft).
Role of policy/state	State as regulators		Investor, producer, net owner, regulator	State as regulator. State still own production, net, but run as commercial org.
Resource mobilization	Large scale: MNC, international funding Small scale: local saving banks/national		Taxation (transmission and power); MNC (users)	Not relevant: lack of investment.
Main actors	MNC, local authorities. Technological companies?	Local authorities	State, MNC, NVE	NVE, Statnett, Statkraft, power intensive industry

5 Preliminary reflections

From the empirical analysis above we may conclude that our conceptual framework seems both meaningful and useful for understanding infrastructure transformation and its interactions with external innovation system dynamics.

We have described how the infrastructure of the electricity system – the grid – has been transformed during a series of historical processes. The intention has been to create a background for an analysis of how Norway can become integrated into the European electricity market. Norway has a limited national market. Expansion in new RETs can be achieved if producers get access to a wider international market. In order to get access to the market the grid has to expand significantly. The historical description present us with some observations which we can use to discuss the feasibility of integrating the Norwegian hydropower system into the European market.

Our first observation is that it seems that in this particular case infrastructure transformation has not been as difficult as could be expected from our conceptual review. In the case electricity grids it seems to be more accurately to talk of *infrastructure expansion* rather than transformation. This type of change might be less dramatic. The empirical analysis illustrated that grid expansion was closely linked to external changes via their impact on demand – both negative and positive in both household and industrial use. It also seems we ought to expand the selection of sources of transformation pressures that Dahmèn identified. Examples are the disappearance of markets, issues of energy security and political visions of an efficient ('perfect') energy market. This is relevant for our analysis of contemporary transformation processes: Does the development of large number of new RETs indicate that we have the transformation is more radical than observed historically – and therefore more problematic to implement?

The second observation is that there have been both internal and external factors driving the transformation processes. We find external factors driving the development during the early 20th century. Electricity production was part of an industrial strategy from large multinational companies as well as local entrepreneurs to develop a new type of industry. In a similar way was the political industrial strategy for a national power system driven by factors exogenous of the electricity system. In both these periods there were strong and dynamic development of power production, consumptions, and development of a power system.

The question regarding contemporary situation is: To what extent are the tensions we observe today sufficiently strong to drive a new transformation process? Another key question is where strong transformation pressures will/can emerge from at all. Historically the electricity system has been transformed due to external, mainly, industrial developments and/or a strong interventionist state (developmental). It is hard to see in the current situation that State or

25

industry could muster such activities. With Norway's current industrial structure/interests, lack of strategic industrial policy, and dominant short-term efficiency logic in policy, it seems that most forces in Norway are working to secure the status quo. This might look different if Norway had a renewable energy industry with prospects of exporting both energy and technology.

A third observation is that the transformation periods historically have been closely linked to wider industrial transformations. Partly the formative periods are characterised by emerging new industries (early 1900s), political driven industrial strategy (after WWII), transforming existing industrial structures (inter-war period), or to de-linking of power and industry (1990s). This indicates that a transformation of the contemporary electricity system should be analysed as part of the wider infrastructure perspective: Developing new grids and integrating Norway into a European electricity system should be linked to the wider issues of transformation of the European economy and industry. It is also closely linked to Norway's industrial development strategy, and also to the political influence of various industrial sectors in the national policy system. How can an industrial policy for Norway contribute to create acceptance for integration into European energy market?

5.1 Wider implications

Our conceptual discussion of how to understand infrastructures, and their roles in innovation-system transformations and low-carbon transition is of general validity. Building and transforming infrastructures is associated with 'more-than-normal' rigidity due to indivisibility, large scale, capital-intensity, externalities, systemness and asset durability.

Our theoretical discussion demonstrated that low-carbon infrastructure projects are crucial to broader development of low-carbon technologies in both the North and the South. In the South this is especially acute due to growth of FDI flowing into Africa from e.g. China, India, and Europe. It is crucial that infrastructure projects are seen as 'technological learning projects' (building infrastructural innovation systems) where local capabilities are developed and the projects are strategically placed within a larger roadmap for low-carbon development. Low-carbon infrastructure is a vital part of building low-carbon innovation systems.

On the basis of our empirical case we can speculate that changes in electricity infrastructure (and in infrastructures more broadly) mainly materialize ex post institutional changes that give incentives for infrastructure transformation. The institutional changes often emerge from the interaction between (a) changing industrial needs (volume and location), (b) political visions, and/or (c) changing household demand (volume and location). Among these it seems that industrial needs have been the primary driver in Norway. In the context of a low-carbon transition (c) is constant or growing but not shifting location (urbanization continues), (a)

26

seems to be constant, and the main driver seems to be (b) which differs strongly across countries and political groups. Without strong industrial demand for changes to electricity system, it could be problematic to achieve transformation currently. A low-carbon transition would (in a non-Norwegian context) imply changing location and type of energy production and out-phase fossil energy driven mainly by political visions without broad industrial backing (industry structure important).

Open questions for further research are inter alia: what are the interesting differences in this respect between developed, emerging and less developed countries? Is it possible to 'leapfrog' in low-carbon infrastructures? China is expanding both energy production and transmission at high velocities. Hence, is gradual expansion better than disruptive expansion/transformation?

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29

Organising principles of transition efforts towards more sustainable food systems: a study of assumptions and sensemaking

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Abstract

In this paper we address the broad question how transition efforts are organised. Clearly, there is no single, ruling entity to direct efforts within and across levels. There are, however, shared assumptions that govern actions and mould on-going transition efforts. What are the assumptions that inspire and organize sustainability interventions? In this paper we label these assumptions about what is at stake and why it should work as 'organising principles'. In addition to the transition literature, this research draws on work in organisational science, in particular on sensemaking (Weick, Sutcliffe, Obstfeld). The basic idea is that in their interpretations and decisions, actors follow particular logics and search heuristics. The social world does not simply appear to people, but is continuously constructed through labels and narratives.

We investigate four policy-initiatives in the German food domain that aim to render food production and consumption practices more sustainable. In the concomitant narratives we investigated assumptions about what is at stake and what will create results. We characterise three sets of basic assumptions or organising principles in transition efforts towards more sustainable food consumption. A first emphasises 'green consumption' through local production and consumption networks or the reduction of food wastes. It is based on the notion of homo economicus: given the right information and (monetary) incentives, people will decide for the more sustainable, i.e. efficiency option. A second organising principle focuses on 'sufficiency', and aims at the consumption reduction of meat and other high-impact food. The underlying idea of man is that of the moral animal wanting the best for itself and others, the homo ethicus. A third principle highlights 'creativity', to be nurtured in spaces and places for collaboration. Here change is expected to stem from communities, social innovation and new, creative ways of doing things. To conclude, we argue that transition efforts may suffer from unacknowledged assumptions about their efficacy.

Introduction

Numerous efforts try to contribute to a transition towards more sustainable societies. Transition research has delivered relevant insights into the multi-actor and multi-level developments involved in regime shifts towards sustainable development. Much thinking and research has also been dedicated to the notion of managing and steering transitions, for example towards sustainability. This raises further questions how the various transformational activities and decisions that form part of a transition interrelate and become organised amidst its occurrence.

In this paper we address the broad question how transition efforts are organised. Clearly, there is no single, ruling entity directing efforts within and across levels. There are, however, *shared assumptions* that govern actions and mould ongoing transition efforts. This research aims to trace such assumptions in current transition efforts towards more sustainable ways of living, thereby answering the question how organising principles in sustainability transitions can be characterised. What are the schemes that inspire sustainability interventions? What are the forces that are expected to be at work? *In this paper we label these assumptions about what is at stake and why it should work as 'organising principles'*. We investigate four policy-initiatives in the German food domain that aim to render food production and consumption practices more sustainable. The rationale of this research is that transition efforts may suffer from unacknowledged assumptions about their efficacy.

Theory

One question is what motivates people in trying to make a difference for themselves, their city and their fellow citizens – and the answers to this question are likely to be as manifold as people are. Another question is what it is that ties the engaged citizens together and towards particular goals. A partial answer is likely to be a shared (and possibly growing) feeling of responsibility for their public spaces. Another answer may be the enjoyment of being allowed to take decisions, to try and test, to learn and discard – and in so doing to implement changes, observe their effects and move on from there. At the same time, knowledge and skills play a role. These observations resonate with findings from creativity research that tries to understand under what conditions opportunities to be curious and explore unfold and where hence creativity can come to the fore (Mumford, 2003).

In addition to the transition literature, this research draws on work in organisational science, in particular on *sensemaking* (Weick, Sutcliffe, & Obstfeld, 2005). The basic idea is that in their interpretations and decisions, actors follow particular logics and search heuristics. By putting this central we also relate to the conceptual work of Grin and van Staveren (2007) who stressed the so-called "system-innovating core idea" in transition processes to foster support among important stakeholders and to ensure lasting system-innovating changes. Just like others before them (Hoppe, 2010), Grin and van Staveren emphasise that in order to achieve system change, also the definition of problems, the search for solutions and the production of knowledge need to change. A system-innovating core idea can potentially support such innovations in the framing of problems and guiding the search for solutions.

In his famous book on *Sensemaking in Organizations*, Karl Weick (1995) identified seven aspects of sensemaking processes. The social world does not simply appear to people, but continuously constructed through labels and narratives. Weick presents and develops his ideas in the following seven aspects:

1. Identity: it is constructed who the "I" or "we" is;
2. Retrospective: looking backward to make sense of what happened;
3. Enactive: people simultaneously interpret and create their world;
4. Social: it is never an indivual achievement, but deeply social;
5. Ongoing: sensemaking never starts and never stops;
6. Extracting cues: people use 'cues', or points of reference, that enable sensemaking;
7. Plausibility over accuracy: plausible representations matter more than accurate ones.

This paper explores assumptions about (i) what is at stake and (ii) why it should work. We have selected four policy initiatives that aim to support more sustainable food production and consumption practices in Germany. Given the interest in assumptions and sensemaking, we focus on the narratives in which the efforts are embedded:

> *First, sensemaking occurs when a flow of organizational circumstances is turned into words and salient categories. Second, organizing itself is embodied in written and spoken texts. Third, reading, writing, conversing and editing are crucial actions that serve as the media through which the invisible hand of institutions shapes conduct...* (Weick et al., 2005, p. 409).

In the discussion we focus on how in the narratives we found, shared views on human beings, their choices and behaviours as well as societal challenges and their possible solutions can be found and what they imply.

Methods

Strictly speaking, it can only be decided in hindsight whether a transition occurred at all and how a given project or initiative contributed to it. Yet many actors partake and give shape to changes underway and engage in various activities that are inspired by an envisioned transition. In this paper, these activities are conceptualised as “transition efforts”.

We examined four policy initiatives aimed at supporting more sustainable practices with respect to food consumption routines. The cases chosen are all based in Germany and include the *Bio-Siegel*, the label marking organic produce that was introduced in Germany in 2001, the *aid-Ernährungsführerschein (food licence)* for primary school children, the *Zu gut für die Tonne (Too Good for the Bin)* initiative that aims to reduce food waste and *Die Essbare Stadt (The Edible City)*, an urban farming initiative in the city of Andernach. This selection of cases is motivated by the attempt to cover a range of approaches and instruments across which organising principles are traced in the analysis. Table 1 provides an overview to capture the variety covered in terms of the implementing policy levels and the employed instruments.

Table 1 Overview of selected cases

Case	**Implementing policy levels**			**Instruments**				
	federal	state	municipal	regulatory	economic	informational	infrastructural	institutional
Organic Label	x			x		x		x
Food waste initiative	x		x			x	x	x
Food Licence	x	x	x		x	x		x
The Edible City			x		x	x	x	x

For each of the cases, web-based information was collected for structured comparison. We focused on the actors involved in the initiative, the targets pursued, the theoretical framework used, the instruments employed, the projects, products or activities implemented that form part of the initiative as well as its direct and indirect effects. In one case, information from the Internet was supplemented by an interview with one of the initiators and managers of the initiative to retrieve additional information about (measured) effects. Based on the narratives we encountered, an analysis was conducted of the (frequently implicit) assumptions and logics underlying each initiative. We will first present the four cases and then discuss the assumptions and sensemaking aspects.

Results: four cases

case 1: The organic food label – Das Bio-Siegel

In September 2001 (BMELV), Germany introduced a label for all produce compliant with the Council Regulation (EEC) No 2092/91 on organic farming and agriculture (EEC, 1991). The declared goal of this policy initiative was to establish a single, known, trusted and transparent label for organic food in Germany to replace the many logos in use at the time that each adhered to different standards. The *Bio-Siegel* initiative therefore involved the national recognition and more rigorous implementation of international standards as well as frequent, at least yearly, assessments by independent, certified controllers. The percentage of agricultural land used for organic production has increased from 1.6% in 1994, to 3.7% in 2001 and to 6.1% in 2011 (BMELV).[1] Since the introduction of the Bio-Siegel in September 2001 and December 2012, the amount of registered Bio-Siegel products has increased from just over 1,200 to almost 66,000 (BLE, 2012) and continues to rise despite the existence of an EU logo for organic produce since July 2012. The EU logo is based on the same standards and its use is obligatory for all organic produce compliant with those. German producers or retailers are nevertheless still allowed to apply for and use the German Bio-Siegel in addition to the obligatory EU logo (European Commission, 2010).

Although this analysis is not meant as effectiveness evaluation of each initiative, it is worth pondering whether the declared goal has been achieved. The Ministry aimed to strengthen internationally agreed standards by creating a single, uniform organic label accompanied by a control system that rendered all labels based on lower standards less trustworthy. The co-existence of several labels persists, however. The obligatory EU logo for organic products, which is based on the same standards, has not substituted the Bio-Siegel in the first eleven months of its existence. Instead, the, among German consumers much better known, Bio-Siegel is frequently featured alongside the EU logo. A number of initiatives by producers and retailers, e.g. *Bioland*, *Naturland* and *demeter*, make use of stricter standards and continue using their labels in addition to the EU logo as well as the Bio-Siegel. In addition, most retailers have created their own, easily recognisable organic brands and display the EU logo, occasionally accompanied by the German label, not necessarily prominently on the package.

The declared goals of the Bio-Siegel were to emphasise EU standards for organic farming and to offer guidance for consumers through the jungle of existing labels and claims. This host of logos, labels and claims about ‘environmentally friendly’ and ‘ecological’ products on the market was hence the problem targeted by means of a uniform label and supplementary information via online and print media about the design, meaning and control mechanisms behind the label.

[1] These figures nicely show that the increase in organic agriculture is not (at least not in its entirety) due to the labelling initiative as its proportion of the total amount of cultivated land increased prior to the introduction to the label already.

The key assumption underlying the use of a label on products is that provided all necessary and relevant information people will make the appropriate decision. As necessary and relevant is deemed that particular detail which is thought to orient people towards the desired decision, in this case the organic product. Policymakers, often supported by scientists and stakeholders, decide what the particular piece of information shared is – obviously confined by the amount of information that can be displayed on a product and the level of detail that is sensible to communicate at the point of decision making. For the Bio-Siegel, it was decided to communicate to people that the product they considered purchasing was organically produced in accordance with EU legislation.[2] The EU-wide successor solely shows a stylised leaf made of twelve stars against green background. The lack of explicit mentioning of "eco", "bio", or "organic" in writing, may, in addition to the former label being a decade older and hence better known, be one of the reasons why many producers and retailers continue using the Bio-Siegel in addition to the EU logo.

case 2: The food waste initiative – Zu gut für die Tonne (Too good for the bin)

Upon its premier in Germany in February 2011 the documentary Taste the Waste triggered a public debate with its description of how approximately 50% of all food in Germany is wasted on its way from the field to the plate. The Federal Ministry for Food, Agriculture and Consumer Protection (BMELV) subsequently entrusted the University of Stuttgart with a study to determine the actual amount of food waste and to evaluate strategies for reduction. In March 2012, the BMELV hosted a conference with stakeholders from industry, retail, gastronomy, agriculture, consumer organisations and NGOs to present the research findings (e.g. about 30% of all food bought by private households is thrown away (Kranert et al., 2012)) and to discuss cooperative strategies for food waste reduction.

In March 2012 a nation-wide awareness campaign under the banner "Teller oder Tonne" *(Plate or bin)* started off targeting the best before date and its appropriate interpretation. In April the BMELV launched the "Zu gut für die Tonne" *(Too good for the bin)* initiative which consists of a number of instruments, e.g. a website and an app to inform private households about food waste and how to avoid it, a number of action days in different cities in cooperation with the *Bundesverband Deutsche Tafel* (an organisation collecting food from restaurants and supermarkets that would be thrown away but is still edible and offers it for free or at very low cost to the poor), churches and Slow Food Deutschland to raise awareness and cooperation with the German hotel and restaurant association to, amongst other, establish doggy bags and offer varied dish sizes.

A survey conducted in March 2012 showed that 81% of the German population above the age of 18 had taken notice of the discussion on food waste in the media and about 20% (23% of the female and 14% of the male population) stated they had already made changes to their ways of dealing with food

[2] The label reads "Bio nach EG-Öko-Verordnung" which means "Organic according to EU-Eco-Directive".

and food waste (BMELV, 2012). Unfortunately, the survey did not ask for specifics about new behaviours or strategies adopted. In November 2012, Infratest dimap conducted a representative survey to evaluate aspects of their food waste initiative. Key findings were that 95% of the German population support the goal to reduce food waste and 51% had heard about the BMELV food waste initiative. 26% stated that they are handling food more consciously while 73% said they hardly changed their behaviours. 97% of the people survey consider *Tafel* initiatives worth supporting and 50% could "certainly" and 35% "potentially" imagine becoming personally involved (Infratest dimap, 2012). In other words, in terms of awareness and good intentions the food waste initiative delivered impressive results while actual changes remained unmonitored.

In the context of this initiative food waste is defined as the problem to be addressed and the set target is to half the disposal of all edible food waste in the EU by 2020, in reference to the European Commission's Roadmap to a Resource Efficient Europe (2011). Since the BMELV food waste initiative is composed of several informative, institutional and infrastructural instruments, a number of assumptions with respect to what the different instruments are able to help achieving need differentiation. The deployment of media awareness campaigns and action days assume that temporary information provision will entail long-lasting behaviour change. The assumption underlying the website and app is that continuously available information (e.g. a database with leftover recipes) will continuously be made use of to help to reduce food waste. Furthermore, the endorsement of doggy bags in restaurants and different portion sizes targets social norms and institutions.

In comparison to the previous initiative on organic food that did not involve any significant change in habits aside from picking the products bearing an organic label from supermarket shelves, this initiative on food waste asks people to do quite a number of things rather differently. It openly addresses the issue that buying more than needed is "bad", for the own wallet and for the environment. Yet in case one has bought too much (in particular retailers and restaurants) and cannot consume or sell it all, there should be regard for others and Christian, if not human values require sharing the superfluous with others who have little. However, these moral appeals are not made by explicit and demanding, possibly to not evoke the criticism of trying to interfere too much into people's choices.

case 3: A Food Licence for children – Der aid-Ernährunsführerschein

The Food Licence initiative forms part of the IN FORM programme, a national action plan for the prevention of malnutrition, lack of physical exercise, overweight and related diseases by the BMELV and targets primary school children aged eight to nine (BMELV & BMU, 2011). Children at the age of 8 or 9 learn about a healthy diet, food preparation, hygiene and table manners in six or seven practical sessions, including two playful "assessments" in form of a quiz and a practical test. The initiative offers an information kit for teachers including letters to parents in several languages and a presentation to explain the aims and content of the Food Licence to colleagues and parents as well as the service to hire an expert to join the sessions. In addition, a booklet is provided to children with explanations, tasks and recipes. By March 2013, after six years of its existence, over 580.000 children had acquired a Food Licence.

In each of the sessions, a different theme is central, e.g. breakfast, salads, cold snacks or warm dishes, yet the goal to teach theoretical knowledge whilst practicing skills and enjoying the activities remains. Children are supported in reading and experimenting with recipes and carrying out all tasks as independently as possible (aid). An evaluation among 77 classes across Germany found that the initiative has positive and lasting effects (tested after 6 months) with respect to knowledge, motivation, competences and behaviours related to a healthy and varied diet, food preparation, hygiene and table manners. The evaluation also showed that children greatly enjoyed participating. Parents noted that children were keener to help with grocery shopping and food preparation and also paid more attention to hygiene and table manners (Sommer, Ekert, & Otto, 2011).

This initiative frames a healthy and more sustainable lifestyle as one involving a balanced diet including freshly made food. The problems targeted by means of information for teachers and parents and practical sessions for children are the dwindling knowledge about what constitutes a healthy diet and skills to prepare self-made food. The keys to success that trigger long-lasting knowledge and behaviour change appear to be experience and experimentation rather than lecturing and indoctrination. Interestingly, the initiative developers and implementers are considering to broaden the efforts to also include parents, e.g. during afternoon sessions with and without their children. Children have some, albeit little influence on parents' grocery shopping and cooking practices. Getting parents aboard helps to embed changes and motivation triggered into the families' everyday lives and also achieve healthier food consumption among adults.

case 4: Public urban gardening – Die Essbare Stadt (The edible city)

In 2010, the garden architect Heike Boomgarden and the geo-ecologist Lutz Kosack who works at the municipal urban planning department of the city of Andernach developed a concept of urban agriculture with the aims to reduce care and maintenance cost of public green spaces, to provide employment and qualification opportunities for long-term unemployed, to improve the city's eco-balance[3] and to make people aware that public space is their space, e.g. by allowing them to pick herbs and ripe fruits and vegetables for free and involving volunteers in care-taking.

This urban gardening initiative runs by the name "The Edible City" and does not follow a fully worked out project implementation plan. Instead, the plan evolves and subsequent steps emerge as the

[3] For example, by using no fertiliser, herbicides and pesticides and planting domestic plant species mostly – also to the great enjoyment of domestic animal species.

project develops. This is remarkable since public expenditures are often tied to specific targets and require detailed planning. Since no additional cost were involved, however, the municipality gave the project managers plenty of rope and allowed testing different approaches and letting the project grow slowly according to its own speed.

Three and a half years later, the initiative has expanded from the permaculture project that had already been in place outside city borders and provided training and work for long-term unemployed to agricultural plots in a number of sites throughout the city, the most prominent being a large plot in the moat of the old castle in the city. Numerous citizens, school classes and voluntary groups are supporting maintenance of public plots or created gardens on their own premises, an organic fair trade shop is selling the permaculture produce in the city centre and urban agriculture courses and workshops are offered by Boomgaarden, Kosack and other experts to interested locals and externals. Over the years, Andernach has won the internationally recognised gold award of the *Entente Florale* twice and a national gold award “liveable city”. Since the early stages of this initiative, the project implementers sought close cooperation with local and regional media, also to inform citizens about plans and intentions and to invite them to join. After Andernach won the Entente Florale for the second time in 2012, also national newspapers and television channels have featured this successful initiative and the project managers and implementers in Andernach like to take credit for the several initiatives that have started to take shape in other cities since then (Boomgaarden, 2013).

Especially elderly were sceptical about the success of the project as vegetable plots in every available corner reminded them of post-war experiences. Generally, people doubted this initiative would be long-lasting and having an impact. However, after initial hesitation to pick food for free, people increasingly dared to take what is available. People’s motivations to make use of the free food and become involved range from saving money, to eating healthier and more varied, to educate children about domestic plants, how they grow, taste, etc. The municipality’s fear of vandalism has proven to be unnecessary (Kosak).

The urban gardening initiative in Andernach is directed at a number of problems its developers identified, including the tight public budgets, long-term unemployment, keeping a city attractive to young people and families, decreasing external recognition and interest (e.g. few tourists) as well as lost knowledge about gardening, domestic species and healthy and fresh food among the general population. Furthermore, the conceivers of this initiative considered it a pity that citizens do not view public space to be owned by and available to them but rather to be “private” property of the municipality. The instruments chosen to address these problems are a different spending of the available green keeping budgets, namely wherever suitable and possible to grow food in public spaces that previously featured lawns and flower beds, the employment of long-term unemployed and invitations to citizens to pick free food and become involved. After a while demand triggered the development of courses and workshops which were subsequently added to the set of instruments employed.

Discussion and conclusion

The following table summarises the preliminary outcomes of the preceding description and reflection on the four cases considered and will be discussed below.

Table 2 Summary table of results based on case analysis

Case(s)	• Organic food label (Biosiegel) • Food waste initiative (Zu gut für die Tonne)	• Food waste initiative (Zu gut für die Tonne)	• Food Licence for school children • The Edible City of Andernach
Focus	Consumption patterns	Consumption levels	Ways of living
Goal	Adaptations of existing practices to include "more sustainable" choices for the sake of the environment	Adaptation of existing and adoption of new practices to reduce consumption and share with others in need	Changes in the city's infrastructure to accommodate new ways of producing and consuming
Defined problems	Lack of awareness about implications of current practices and alternative consumption choices	Lack of awareness about implications of current practices and lack of knowledge and skills to change those	Decreased attractiveness of the city for young people and families, long-term unemployment, lack of knowledge and skills to engage in new production and consumption practices
Tools	Campaigning and information (on a package or through print and online media)	Campaigning and information (print and online, also action days)	Spaces and places for collaboration and innovation
Notion of human being	Homo eco-economicus	Homo economicus moralis	Homo creativus
Organising principle	**Green consumption**	**Sufficiency**	**Creativity**

In the *organic food label case*, the assumption was that given the appropriate information, people will make an informed and intelligent decision. This assumption is tied to a notion of the human being as a rational actor. Usually, alerting stickers or labels on products or shelves communicate to people "buy this bargain", with personal profit maximisation (or personal cost minimisation) as the only factor considered to play a role in rational decision-making. However, displaying a label that bespeaks a production method less harmful to the environment and the consumer and thereby partially explains higher purchasing cost involves a broader definition of profit- or utility-maximisation. In addition to money, also personal health, environmental protection and animal welfare enter the equation.[4]

The notion of the human being as a rational actor capable to take all information into account and solely focused on maximum utility has been challenged in economics, psychology and sociology alike. It has, for example, been shown that intentional, motivational factors and perceived control play a role in decision-making (Ajzen, 1991), that decision-making is based on bounded rationality (Simon, 1991). In addition, practice theories discuss how behaviours relate to social norms and are embedded in systems of provision and institutional contexts (e.g. Shove, Pantzar, & Watson, 2012). To remain in the mathematical analogy, there are hence numerous factors that enter or are excluded from the equation that makes for the outcome of a decision-making process after dependant on the kind of choice being made, careful weighing of available options and potential consequences or not much conscious consideration at all.

We noted above that the use of an eco-label broadens the notion of rationality from purely monetary gains to include environmental and health benefits.[5] In more detail, its use assumes a careful and conscious decision-making process that includes taking note of the label as well as a genuine interest in and concern for the environment that cause the decision-maker to make a positive purchasing decision based on (knowing) what the label denotes. One way to frame the notion of the human being at work when choosing a label to inform about organic produce is hence that of the *homo economicus* yet with ecological concerns, i.e. a *homo eco-economicus*.

Labels are a (common) way for policymakers to engage in transition efforts towards more sustainable ways of living. The Bio-Siegel as an example from the food domain is rather representative for eco-labels in trying to communicate about a “more sustainable” product while at the same time justifying its higher purchasing price. From the perspective of the consumer, a label hopes to provide sought for information and to trigger a reasoning and feeling along the lines of “I may be paying more yet the label tells me I am doing something good”. From the perspective of producers and retailers, a label hopes to set inspirational and aspirational standards that are pursued for economic as well as ecologic reasons. A label can, therefore, be conceptualised as an instrument that aims to organise producers, retailers and consumers around a shared view on the importance of high-standard produce that motivates and justifies higher expenditures.

In other words, a label can be viewed as forming part of a cluster of transition efforts that involve doing the same things (e.g. growing crops, fruits and vegetables and breeding animals, harvesting and culling, processing and packaging, transporting and selling, buying and consuming) yet now in line with particular, supposedly more sustainable standards that differ from “mainstream” regime

4 Needless to say, the idea of people as rational actors is carefully
5 In CSR-speak this is frequently denoted as concern for people, planet and profit.

standards. These efforts can be viewed as being organised by a "principle of green consumption" following the idea of doing the same things as previously along the production-consumption chain, yet somewhat differently[6]. On the part of the consumer, these transition efforts organised by "green consumption" hardly require any changes, especially since most supermarkets in Germany offer a broad range of organic products today.

Ironically, the purchase and consumption of organic products does not necessarily require consumers to go much out of their way yet it is frequently sold as making a "great deal of difference" in the form of more sustainable consumption when promoting "green" products to enhance the feel-good factor amongst consumers or to justify expenditures and (self-)praise government interventions. In short, labelling initiatives address consumption patterns and systems of provision rather than consumption levels.

Also in *the food waste initiative* assumptions appear of the human being as rational actor with self-interest but also moral motives. On the one hand, people are being made aware of how much money they are throwing into the bin with every still edible food item they are disposing of and about the detrimental effects this has on the environment. In this respect, the *homo eco-economicus* can again be considered as the underlying notion of what makes people tick and what they base their choices on as the choices made should be rational albeit considerate for social and environmental repercussions.

On the other hand, there is an appeal to people's conscience by raising awareness for others in society who can hardly cater for their own subsistence and who should he supported and shared with. The use of moral arguments and the cooperation with churches alludes to a slightly different notion of the human being than the one that makes rational choices based on a broad set of factors, including environmental. Within the moral appeal lies the assumption (or hope) that people's altruistic regard for others and their needs enters the equation and tips its outcome towards more sustainable behaviours. The notion underpinning this assumption can be framed as a *homo moralis* who avoids wasteful behaviours based on the concern for others' needs.

Assuming the chosen instruments to be effective and implementing them entails effects from the moment of deciding to take action[7]. The currently chosen instruments area means to engage a number of stakeholders in collective campaigning to raise awareness and to promote less wasteful consumption patterns. In addition to consumption patterns, this initiative also addresses household consumption levels by educating about appropriate ways to plan grocery shopping, finishing left-overs

[6] This formulation is not intending to belittle all the work, changes and investments that have to go into converting a conventional into an organic farm. For the sake of the argument, however, it needs to be clear that "in principle" many norms and ways of doing things remain untouched albeit becoming aligned with a particular set of standards.

[7] Albeit possibly not the effects aimed at in the form of a 50% cut on edible food waste by 2020. There may be numerous other, possibly more effective ways to support changes for food waste reduction, some of which were also proposed in the study carried out at the behest of the BMELV in the aftermath of the Taste the Waste movie (Kranert, et al., 2012)

and still edible products beyond the expiration date as well as passing on what oneself will not use to others in need. Trying to gain an understanding of what kind of principles are giving direction to the different activities stakeholders engage in around the BMELV food waste initiative raises the question of what is asked for by and from the different stakeholder groups involved, e.g. policymakers, campaigners, churches, NGOs, consumers, what is deemed an appropriate measure to take and more sustainable practices to engage in.

A close look reveals two principles that underlie these efforts towards more sustainable consumption. Similarly to the previous case, a “principle of green consumption” is at work which frames and gives meaning to efforts that hope to make current practices more sustainable by means of slight variations, e.g. making better use of left-overs or only throwing away products that have actually gone off and not just passed the expiration date.

In contrast, a “principle of sufficiency” underlies the replacement of old ways of doing things by new and different ones that involve reduction and abstinence, e.g. better planning and only buying what is needed or donating still edible food waste to others in need. As part of the food waste initiative, people are not explicitly asked to restrain themselves possibly because policy does not want to appear to dictate “appropriate behaviours”. However, people are asked to consume carefully and share what is too much with others who have too little.

In regard of the declared goal (i.e. halving food waste) and the selected instruments (i.e. website, app, action days, campaigns) both principles work in parallel and complementarily. The stakeholder alliances formed and the measures taken to educate about, motivate and support different (i.e. same consumption yet green) or new (i.e. different, reduced consumption) practices to handle food are the same for each principle. Since the reduction of food waste is a comprehensive goal which relates to a number of interrelated practices, involves a considerable amount of knowledge and skills and relies on systems of provision some of which clearly favour wasteful consumption, myriad changes are needed to make any progress towards the desired goal at all. Therefore, it may come as no surprise that different approaches and arguments are used that are based on a couple of different notions of human beings and that a couple of principles frame and give meaning to the different efforts implemented.

In the *food licence for children case*, the view on human nature and what motivates more sustainable behaviours this initiative assumes is different than that of the others discussed above, probably because it is currently primarily aimed at children. Instead of providing information to be passively absorbed, the Food Licence bets on attitude and behaviour change through playful, experiential and experimental learning and practicing. The sessions try to encourage children to try out new practices, under supervision and with guidance, of course, but children should feel comfortable to do what they like and follow their intuition. This notion of human experience and behaviour can be conceptualised in the idea of a *homo creativus* who follows own ideas and intuitions whilst applying knowledge (what is healthy), norms (what is appropriate behaviour), skills (how it is practically done) and rules (recipes).

The conception of people, i.e. the notion of the *homo creativus*, that underlies this initiative acknowledges the importance of creative and playful experience and experimentation in addition to the acquisition of skills and knowledge. The centrality of creativity, experience and experimentation is shared by groups of stakeholders who become involved financially or in kind and who help implementing and further developing this initiative. Furthermore, the assumptions about what works and what does not work when trying to engage people in more sustainable practices which is captured in the notion of the *homo creativus* ties the chosen instruments to the defined problems and targets. The particular strategies and instruments chosen only make sense and become meaningful in the context of these assumptions. Therefore, the principle that organises and shapes these efforts can also be described as a “principle of creativity” that does not prescribe and indoctrinate but offers inspiration and possible directions and motivates to find own ways.

In comparison of the cases described above, the *public gardening case* one stands out by deliberately not educating and informing people about what they should do better or differently, unless they ask. Available budgets and infrastructures were directed at different goals and an invitation was extended to the population without requirements and strings attached. In doing so, the city environment changed into one that “demonstrates”, “tells” and “informs” about healthy and sustainable food. The success of the municipality to try to inspire, engage and involve citizens can also be measured in the inquisitiveness triggered. Courses and workshops were developed because people want to learn about urban gardening and to help strengthening or even reintroduce domestic species. Some people are even collecting seeds from domestic plants that grow in the surroundings of the city and enquire whether these may be suitable for growing within its borders. In terms of other goals met, it can be stated that tourism has increased over the past years also due to visitors from other municipalities who would like to learn about experiences made in Andernach first hand (Andernach City Council; Kosak).

The fact that all these developments cascaded from the “simple” decision to invest money slightly differently for growing different plants in some areas of the city, i.e. to make a change to people’s environment, supports the conclusion that the underlying notion of the human being as a playful, creative animal is a successful one in striving for support and engagement. People even ask for more knowledge, tools and skills and sign up for courses. This enthusiasm and involvement bespeaks a desire for being inspired to take individual and collective action.

Coming back to a central concern of this analysis, *homo creativus* can again be noted as the underlying notion of human beings in this initiative. In comparison to the previous case, the recognition of the creative streak of people and their desire to experience and experiment are even more strongly pronounced here as not only participants at the receiving end are invited to engage creatively, but also the developers and implementers of the initiative themselves. There is no set-in-stone plan yet every step provides insights and ideas for the ensuing one.

These observations offer fertile ground for reflections on the role and functioning of organising principles. It is frequently supposed that powerful visions can provide inspiration and guidance towards desired goals which may explain the plethora of visions, roadmaps and strategies forms part of current transition efforts, in the business, research policy as well as the civil society domain (Backhaus, Breukers, Mont, Paukovic, & Mourik, 2011). However, in this case no uniform vision existed, solely a number of ideas that are bit-by-bit brought to life and amidst their implementation cause new plans and ideas to sprout.

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Interests, expectations, and agency regarding electric vehicle recharging infrastructures

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DRAFT VERSION

Abstract

With this paper I aim to address both issues: how and why various actors may support or hinder transitions and how and why they try to influence the shaping of the new system. I draw from a case study on the transition towards electric automobility in the Netherlands. The analysis starts from the hypothesis that strategic rationales of niche actors vary and that these depend on their interests and expectations in relation to the emerging system. Actor strategies encompass more than simply supporting or blocking the transition and I pay special attention to their attempts to influence the technological and organizational design of the emerging socio-technical system. For electricity producers and grid operators, the electric vehicle poses an opportunity as well as a threat. Learning about the actual impact and mitigating any negative impacts are their main strategic rationales for joining the EV niche. From the analysis, in total 9 different, but mostly complementary, strategic rationales of niche actors can be distilled: Marketing, Social responsibility, Adapting to regulations, Developing new business, Leaning about opportunities, Learning about threats, Influencing the configuration of the emerging system, Influencing the configuration of an existing system. These go to show that it is not only a straightforward positive interest that motivates niche actors. However, the support from these actors is conditional and they are likely to end their support as soon as the emerging system no longer aligns with their interests.

1. Introduction

The role of agency in socio-technical transitions has received only limited attention so far, despite several calls to fill this gap (Smith et al. 2005; Shove et al. 2007; Genus et al. 2008). Furthermore, insofar as agency is addressed in the literature, its treatment is limited to the question whether specific actors support a transition or try to hinder it. By and large, this depiction of actors and their agency is directly related to the dichotomy between old systems and incumbent actors on the one hand and newly emerging systems and typical niche actors on the other. In other words, albeit somewhat overstated, newcomers make transitions happen and incumbent regime actors try to hinder them. Because of this depiction of actor roles, the transitions literature risks losing sight of the diversity in the roles that different types of actors might play and the various rationales that underlie their behavior. Furthermore, and perhaps more importantly, it thereby fails to address the role of agency in the shaping of new socio-technical systems that are to result from transitions. That is to say, it is likely that actors have different preferences for specific configurations of the newly emerging systems. Through their involvement in the niche, they strive to influence the direction of the developments accordingly. With this paper I aim to address both issues: how and why various actors may support or hinder transitions and how and why they try to influence the shaping of the new system. In order to do so, I draw from a case study on the transition towards electric automobility in the Netherlands. I thereby focus on the build-up of a nationwide electric vehicle recharging infrastructure.

The analysis presented in this paper starts from the hypothesis that rationales and resulting strategies vary among the actors and that these depend on their current and future interests in relation to the emerging system. How these actors subsequently value the emerging system and its impact on their interests (positive or negative), depends upon their expectations of the emerging system. I therefore analyze both the interests and expectations of actors in order to explain their rationales and strategies. As said, their strategies are likely to encompass more than simply supporting or blocking the transition. I therefore pay special attention to their attempts to influence the technological and organizational design of the emerging socio-technical system. Because the actors' interests are likely to depend upon the ultimate configuration of the system, they can be expected to try to influence its ultimate configuration. Finally, I consider several conflicts of interest between the actors that actually or potentially result in conflicting strategies, which could eventually hamper the transition. More specifically, disputes over the configuration of the system might cause some actors to withdraw their support in case the resulting configuration no longer aligns with their interests.

2. Theoretical background: agency in transitions

Transition studies deal with large-scale and radical system innovation (e.g. the type of innovation that is needed for the introduction of EVs in the transport system) that requires cooperation among a broad set of actors (Elzen et al. 2005; Geels 2012). Cooperation between these actors can however not be taken for granted. Instead, the transitions perspective emphasizes that new and emerging socio-technical systems typically face resistance from the existing system (or *regime*) (Smith et al. 2005; Hekkert et al. 2009). Such resistance may be passive, resulting from existing institutions (formal and informal 'rules') that exclude the new technology or emerging system. It may also be active resistance, as with deliberate resistance from actors with interests in the existing system. To shield the newly emerging socio-technical system from such resistance and to provide it a chance to develop further, a variety of actors may create 'protected spaces' in which the emerging socio-technical system can be developed until it is mature enough to confront the existing regime (Vergragt 1988; Kemp et al. 2001; Smith et al. 2012). The necessary protection can be provided by governments (through R&D programs, support for pilot projects, and favorable (financial) policies), as well as by other actors who have some interest in the development of the new system. The space that is created as a result of the protection of the emerging system, i.e. the technological niche, can be understood and conceptualized in several ways. A niche can be understood as a local experiment in which a limited set of actors experiments with a new technology in a real-life situation. This understanding of niches was more or less common in the earliest literature on Strategic Niche Management, and the accumulation of several local niches was expected to result in broader developments that eventually culminate to large-scale transitions. In this paper I build on a broader understanding of the niche concept that starts from a socio-cognitive perspective. From such a perspective, a niche provides a socio-cognitive framework that enables all sorts of local activities. Such a broader conceptualization of niches allows for the inclusion and accumulation of governmental regulations that trigger and support innovation and resulting activities and statements of individual actors (worldwide). A niche is thus continuously held up by several actors, who provide protection in all sorts of ways, and at the same time, those or other actors can draw from it as well. In the remainder of this paper I will speak of 'actors joining a niche'. Obviously, however, niches do not simply pre-exist and they are continuously held up by its members. Joining a niche is thus never free of charge and niche actors contribute for instance financially or at least discursively.

Several papers have called for more explicit accounts of the role of agency in transitions (Smith et al. 2005; Shove et al. 2007; Genus et al. 2008). Others, have pointed to the fact that agency has always been very much a part of the analysis and conceptualization of transitions, as far as the the MLP goes at least. As Geels put it: *"the MLP is shot through with agency, because the trajectories and multi-level alignments are always enacted by social groups. The Y-axis, which refers to 'increasing structuration of activities in local practices', indicates that the different structural levels are continuously reproduced and enacted by actors in concrete activities"* (Geels 2011). One could however still argue that such a treatment of agency is too implicit and most of all too descriptive without providing any clues about why some actors are, and some actors are not, enacting a transition. Indeed, several studies have addressed such issues in terms of power (Avelino et al. 2009; Grin et al. 2010) or the politics of transitions, including interests, (Meadowcroft 2009; Kern 2011). While these studies do take agency into account explicitly, I would argue that they do so only in rather shallow way. These studies rely too much on a simple dichotomy between proponents and opponents of transitions. As mentioned in the introduction, this dichotomy is (too) often related to the dichotomy between actors that have vested interests in the old system (regime actors) and new-entrants that only have an interest in the new system (niche actors).

In the remainder of this section I elaborate on two concepts that are crucial to understanding actor involvement in niche: interests and expectations. While the transitions community often refers to interests in general and to vested interests of incumbent actors specifically, it has not really embraced the concept or elaborated its precise role. In the following I will argue how it can be used in a meaningful way. Since niche activities are by definition anticipatory (i.e. actors in the niche anticipate a future in which a transition is to take place), expectations about various aspects of the transition must play a role in their decision making (Borup et al. 2006; Bakker et al. 2012).

2.1. Interests

Interests can be defined as the most basic objectives of an actor. In general one could expect that survival is that basic objective of all actors, but depending on the context and specific type and role of the actor, more articulated interests can be attributed to individual or groups of actors (Woll 2008). The importance of interests in guiding agency in transitions has been widely acknowledged in the literature (Unruh 2000; Smith et al. 2005; Avelino et al. 2009; Meadowcroft 2009; Smith et al. 2010; Geels 2012). Nevertheless, discussions regarding the role of interests (and the power to protect these interests) are still limited to the crude distinction between the vested interests of incumbent actors and the emerging interests of new entrants active within the niche. In the context of transitions such interests can thus indeed relate tot sustaining old business models and the existing dominant design in an industry. But it could also be that incumbent actors recognized that the newly emerging system aligns with their interests as well. In fact, there is quite some literature that addresses and acknowledges such a supportive role of incumbent actors in several transitions (Dyerson et al. 2005; Hockerts et al. 2010; Sierzchula et al. 2012; Wesseling et al. 2013). At the same time one can question their strategies and suspect that their actions are merely a matter of green washing or window dressing, as has been argued in the case of electric vehicles as well (van den Hoed 2005; Wells et al. 2012). The same suspicions can also be raised for some of the more typical niche actors: what are their interests precisely and are they, for instance, not only interested in the governmental subsidies that are available in the niche? Whatever the precise strategic rationale of the different actors is, niche actors help to create and sustain a technological niche because it somehow aligns with their current or future interests. Obviously such interests vary among actors. First of all, basic interests differ between governments (interests in achieving societal goals), businesses (generating profits) and other types of organizations. Second, on a more detailed and case-specific level, interests are likely to differ between individual actors. In the case of automobility for instance, one could expect that local governments have different interests or different priorities between interests in comparison to national governments. Also, not every car manufacturers share the same interests since all have different product portfolios, technological competences, etc.

Furthermore, depending on the context and the role of different actors in that context, actors are likely to have (or at least to perceive) various interests to have various interests that are not always easily aligned. Some interests might have to be prioritized over others and such prioritizations might be subject to change as well. Governments, for instance, have to balance their interests in economic development with interests in environmental issues. Likewise, the primary interest of a private company is to generate short-term revenues, but at the same time it needs to consider its long term strategy to survive possible changes in its market environment.

Beyond the question of whether actors are proponents or opponents of the emerging system, it is also important to consider the extent to which different configurations of the emerging system (i.e. the different technological, organizational, and institutional design options) align with the interests of actors or rather pose a threat. To illustrate (as this study shows), electricity grid operators could benefit from the large-scale adoption of EVs, but only if the charging of EVs can be controlled and the stability of the grid (i.e., their core interest) is not threatened. The transition to electric mobility as such thus does not necessarily suit their interests. Instead, their interests are crucially dependent upon the integration of smart charging equipment into the EV system, thus enabling them to control charging behavior.

In itself, the concept of interests of actors, individuals or organizations, is difficult to define and study. Although central to economic theories of action, sociologists seem to have a much more troubled relation with the concept (Kern 2011; Geels 2012). (Self-)Interests belong to the realm of rationalistic ideas about action and it presupposes that actors are actually aware of their interests. Sociologists tend to treat interests rather as constructs and thus see any references to interests and the discourse on interests rather as an outcome than as a source of inspiration for action (Swedberg 2005). Also, one could argue, following Geels, that rational calculation of effects of different options may be useful, and possible, in stable times of equilibrium, but are far less useful in times of radical change (Geels 2012).

Still, I would like to argue that (perceived) interests matter in transitions and that we can and should take these into account. To some extent interests might be merely constructs that actors have constructed themselves to legitimize their actions or they might be implied upon them by other actors or institutions, i.e. electricity grid operators are responsible for grid stability and this responsibility, and thus interest, is formalized by law. Regardless of whether interests are real or mere constructs, they do matter insofar as actors take their (perceived) interests into account when making any decisions. In the context of transitions, the uncertainty of such long-term endeavors makes it naturally difficult to assess the impact of certain development upon an actor's interest and at the same time there is uncertainty about ways in which an actor's interest may change over time as well. Even more so, it is likely that their interests will coevolve with technological, organizational, and institutional changes. Still, at some point in time, actors need to decide how to position themselves in relation to actual or proposed transitions and their own perceptions of their interests do matter in terms of their attempts of 'making sense' of what is going on or what is about to happen. Because such sense making is so much an anticipatory activity, expectations about future development play a crucial role as well: what can happen, what is likely to happen, how is this going to affect me? In order to address the complementary role of such expectations, I draw from the sociology of expectations literature. In the following sub-section I elaborate on this literature the concepts and findings that are relevant to this paper.

2.2. Expectations

Positive expectations, when they are part of collective repertoires, are said to stimulate, steer, and coordinate innovation activities between actors. The central claim within the sociology of technological expectations is therefore that positive expectations of an emerging technology are crucial to its further development and eventual success in the market or society in a broader sense (Borup et al. 2006). However, not all relevant actors necessarily share those expectations (Budde et al. 2012; Konrad et al. 2012) and at the same time, actors are likely to have diverging interests as well (Truffer et al. 2008). While the cited authors and others do recognize that different actors have different individual expectations and interests (Berkhout 2006), especially the importance of interests remains rather implicit. In previous work I have studied the role of expectations in the competition between different emerging technologies (van Lente et al. 2010; Bakker et al. 2011). These analyses showed that developers of these technologies engage in expectations work in order to secure a position in public and private R&D agendas. Technology developers make use of positive expectations of their own options, while also voicing explicitly negative opinions about the future potential of the competitors.

Technological expectations, ideas about the potential for improvement of an emerging technology and its future societal and commercial value, thus influence actors' positions towards an innovation trajectory directly and indirectly. Of direct influence are the expectations that are held by the actors themselves: their individual expectations. Indirectly, the actors are influenced by a set of collective expectations that circulate widely in society (or at least in their community) that they need to take into account in their decision making. This distinction between individual and collective expectations is stressed in the expectations literature and it is shown that these are strongly interrelated (Borup et al.

2006; Konrad 2006; Truffer et al. 2008). By and large the expectations-related literature has focused on the role of collective expectations and has shown that these may have a structuring role in guiding innovation trajectories. That is, strong collective expectations are inescapable and actors need to act in line with these generally accepted ideas. For instance in the case of the electric vehicle, the collective (positive) expectations of these cars make that no car manufacturer can afford itself to refrain from developing and (plug-in hybrid) electric car. Electricity suppliers likewise are more or less forced to install at least some recharging points, even when they hold no believe whatsoever in the future of electric automobility.

At the same time, all actors have their own ideas about what the future may bring and try to separate fact from fiction. This is where the distinction between enactors and selectors is relevant again (Rip 2006; Bakker et al. 2011) as the selecting actors make up their minds about the credibility of different circulating expectations and how to act (and invest) accordingly (Bakker et al. 2012).

Technological expectations can further be divided in different levels or types. Van Lente proposed to distinguish between micro-, meso-, and macro-level expectations (van Lente 1993) while Truffer et al make a distinction, that I will follow in this paper, between expectations of the technology itself, of the behavior of other actors, and further contextual expectations (Truffer et al. 2008; Budde et al. 2012). Strictly technological expectations, can be, inspired by van Lente's three levels, further unraveled to a distinction between expectations on the component level, a configuration level, and a system level (Bakker et al. 2011). In the case of electric vehicles this would translate respectively into, among others, expectations about battery technology improvements, expectations about car cost reductions and expectations about the build-up of recharging infrastructures. Expectations about the behavior of other actors relate to the systemic nature of (system-) innovation and the fact that no innovator can act and succeed on its own. Whether or not other actors join in on the innovation trajectory, or possibly whether they form an opposing force, is therefore of major importance. Wider contextual expectations may relate to landscape factors such as oil price development and environmental concerns.

The ways in which different actors respond to both their own individual expectations and the set of collective expectations relates can be expected to depend on their interests and related preferences. That is, an actor may be mildly forced to engage in an innovation trajectory because of strong collective expectations, but is unlikely to do this will full force when it does not fit its (primary) interests. Budde et al have proposed to distinguish between the 'talking' and the 'doing' in this respect: actors may voice opinions and show off some innovation activities that are in line with mainstream expectations (the talking) while actually not 'doing' a lot (Budde 2011). Konrad makes a similar distinction, in relation to the emergence of collective expectations, between discourse activities and innovation activities (Konrad 2006). Konrad also states that individual expectations of actors are, in part, shaped by their interests (Konrad 2006, p.432). I propose to regard individual expectations rather as a set of individually held ideas, although probably heavily inspired by the collective ones, on the basis of which actors decide how to act in accordance with their ideas about their own interests. Individual, intrinsic, expectations and interests are then more clearly separated and it can easily be understood that actors can hold positive believes about the future potential of a technological option even though they do not match their interests. In such a case one could expect an actor to try to hinder the (seemingly unstoppable) innovation trajectory.

3. Methodology

To identify the interests and expectations of actors and the resulting strategies, 38 interviews were conducted with representatives of various actors in the Netherlands. The interviews took place in 2012. The respondents represented national (7) and local governments (4), car manufacturers and importers (8), electricity producers (3), grid operators (4), recharging infrastructure developers and service providers (4), oil companies (3), NGOs (4), and a car leasing company (1). The vast majority of these interviews were conducted in person; three were conducted by telephone, and one (with an oil company) was based on e-mail correspondence, as the request for a formal interview was denied. None of the other interview requests was denied. For reasons of privacy, and in order to stimulate openness during the interviews, company names and the names of the individual respondents are withheld in this paper. The interviews were semi-structured, meaning that a guideline was used in order to ensure that the respondents commented on the following topics:

- Expectations regarding EVs:
    - Expected technological development
    - Expected market potential
- The potential impact of EVs on the organization’s interests:
    - The threats that EVs could pose to the organization
    - The opportunities that EVs could bring to the organization
    - The conditions under which EVs would align with the organization’s interests (i.e., their favored configuration of the system)
- The activities of the organization with regard to EVs:
    - Current activities
    - Future plans
- Perceived obstacles to the introduction and large-scale adoption of EVs
- Experience with counteracting strategies by other organizations

This method was chosen in order to allow respondents to talk freely about their interests, expectations, and strategies regarding EVs. Furthermore, because the most relevant aspects of the market introduction of EVs differ across actor groups, scripted interviews with pre-defined questions would not have allowed us to collect information with the necessary level of detail and variation between the interviews with different types of actors. The last two topics in this list are meant to trigger the interviewees to talk about other actors' strategies as well and to check for any blocking strategies (of incumbent actors).

Based on the interviews, a narrative was written to describe the interests and expectations of each group of actors with regard to the EV system, as well as their resulting strategies. These narratives also address differences within these groups (e.g., differences among grid operators). The respective narratives are based primarily on the interviews with the actors themselves. However, the full series of interviews was used to cross check and, if necessary, complement the actors' descriptions of their own interests and strategies. The interviews with the NGOs and the car-leasing company were used only to cross-check and complement the actor narratives.

4. Findings: electric vehicle recharging infrastructures

The transport sector is facing the challenge of reducing its overall carbon footprint and becoming less dependent upon fossil fuels. For example, the European Commission has adopted a roadmap towards 2050 that aims to reduce carbon emissions and dependency on imported oil by 60%, relative to 1990 levels (European Commission 2011). Because such reductions are particularly difficult to achieve in aviation, shipping and long-distance haulage, even further emission reductions will probably be needed in automobility. While changes in travel patterns and mode choices can certainly contribute to these goals, technological change is needed as well. Although much can be gained from further incremental improvements in conventional drivetrain technologies, increasingly stringent carbon-emission regulations in the EU, the US, and Japan are pushing the automotive industry towards the further commercialization of radical low-emission and zero-emission vehicles (European Expert Group on Future Transport Fuels 2011). The most notable example is the European legislation that requires car manufacturers to reduce the average emissions of their passenger cars to 95 grams of CO_2 per kilometer by 2020 (European Commission 2012). From the variety of technological options that are available to meet this requirement (including biofuels and natural gas), virtually all car manufacturers have placed at least a portion of their bets on fully electric or plug-in hybrid vehicles (Dijk et al. 2012; Sierzchula et al. 2012). After a number of failed attempts in the past, EVs are now a serious option. In contrast to the earlier attempts, they are now actually available on the market (Bakker et al. 2012). The success of the transition toward electric mobility, however, will not depend upon car manufacturers alone. Cooperation among a broad set of actors will be needed in order to produce affordable vehicles, as well as to develop an early market and the necessary recharging infrastructure. In this paper, I discuss and explain such actor strategies in order to gauge whether the transition can be successful and how the electric mobility system will ultimately be configured. The analysis is limited to the Netherlands, although many aspects are likely to play a role in other countries as well.

Previous research regarding the development and commercialization of EVs has focused on either the supply side (by identifying strategies employed in the automotive industry) or the demand side (by gauging consumer acceptance of EVs). Supply-side studies show that, although the automotive industry is developing electric-drive vehicles (including ‘regular’ hybrids, plug-in hybrids, and fuel-cell vehicles), it is doing so as part of a wider portfolio strategy in which the most attention and resources are still geared toward incremental improvements in conventional vehicle technologies (Frenken et al. 2004; Hekkert et al. 2004; Dyerson et al. 2005; Oltra et al. 2009; Sierzchula et al. 2012; Sierzchula et al. 2012; Wells et al. 2012; Wesseling et al. 2013). Demand-side studies show that the vast majority of consumers are unwilling to pay a premium for electric vehicles, given their limited performance in terms of range and recharging times, as well as the lack of a high-density recharging infrastructure (Dimitropoulos et al. 2011; Hidrue et al. 2011; Pearre et al. 2011; Campbell et al. 2012; Graham-Rowe et al. 2012; Lebeau et al. 2012; Schuitema et al. 2013; Tamor et al. 2013). The apparent gap between reluctant car manufacturers and a skeptical market could easily lead to an impasse in the niche developments. Despite this gap, however, a broad range of actors is actively paving the way for the large-scale introduction of EVs. These actors include national and local governments, car manufacturers, the electricity industry, newly started businesses, and even some of the traditional oil companies. In the following analysis, I will focus on two groups of actors: electricity producers and grid operators. First however, I will sketch the context of the developments in the Netherlands.

Governments in virtually all developed countries have implemented policies to support the introduction of EVs. These policies include environmental regulations that force automakers to develop cleaner cars, supportive schemes for R&D and demonstration programs, and various tax exemptions and other means of financial support for consumers. Complementary to these vehicle-centric policies, the realization of a vehicle recharging infrastructure is supported by most countries as well. The Netherlands can be regarded as one of the frontrunners in these developments and the support for EVs. It is the national government’s ambition to make the Netherlands the major experimental garden for EVs in Europe. In practice would mean that the Netherlands is among the first countries where car manufacturers take their first series of EVs. It is expected that car manufacturers select a limited number of countries for their early market introductions of EVs and that they look carefully at the customer incentives that are provided.

Through its support for EVs and the resulting early introduction of EVs, national government strives to achieve significant reductions of CO_2 emissions and perhaps, more importantly, air quality improvements in the four major cities (Amsterdam, Rotterdam, Utrecht, and The Hague). Furthermore, the support for EVs is supposed to lead to economic growth from EV related business opportunities (Ministers van V&W en EZ 2009; Formule E-team 2011). National and local policies have been successful insofar that car manufacturers like Nissan, Renault, and Daimler have agreed to release their EVs in an early stage in the Netherlands as well[1]. Next to national government, other actors have had a big role in the development of the EV niche in the Netherlands as well. Among these, the role of the electricity industry is most interesting for this paper. The two major actor groups in this industry are the electricity producers and the grid operators.

4.1. Electricity producers

The growing use of EVs provides electricity providers with an opportunity to expand their market. In this respect, their interests are relatively straightforward, and they are positively correlated with the increasing adoption of EVs: the more EVs that are in use, the more electricity they can sell. Beyond such a basic market perspective, electricity producers expect that EVs will become a valuable, if not essential, element in future energy systems. The cumulative capacity of the batteries of future EVs could make it possible to store renewable energy in times of energy surplus. Because this energy would be consumed primarily by the EVs themselves, this would largely be a matter of charging cars when energy is abundant. In the long run, EVs may also be used to deliver this energy back to the grid in times of need, thereby helping to balance supply and demand within the electricity market. On the other hand, the large-scale adoption of EVs could also pose a threat to the careful balance between electricity production and use. If large numbers of EVs are plugged in at the same time (e.g., when they arrive at home after work or when the lower night rate starts), the demand for electricity would increase sharply, possibly exceeding the capacity of electricity production.

In order to realize the potential of EVs as energy-storage buffers, and in order to prevent undesirable peak demand, electricity producers see a need for the introduction of much more flexibility in charging rates, thus offering drivers incentives to charge their cars at favorable times whenever

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[1] A company like Nissan makes no secret of the fact that it will only bring its electric model 'Leaf' to a country when there are sufficient governmental (financial) incentives in place for prospective customers. (http://www.nissan-global.com/EN/NEWS/2009/_STORY/090802-02-e.html)

possible. Such dynamic pricing, however, is not yet allowed in the Dutch electricity market. Furthermore, from a technological perspective, current electricity meters in homes differentiate between only two tariffs (day and night), while a much more fine-grained differentiation using 'smart meters' would be needed in order to trigger the desired charging behavior. In fact, the current night tariff encourages EV owners to start charging their cars at the start of the night rate, thus causing a sudden peak in demand.

4.2. Grid operators

As a result of the 2006 law on independent grid operation (Wet Onafhankelijk Netbeheer), electric utilities in the Netherlands have been split into separate electricity producers/retailers and grid operators (Ministry of Economic Affairs 2006). Grid operators are responsible for local electricity-distribution networks (up to 110kV). Similar to electricity producers, EVs pose both an opportunity and a threat. For grid operators, however, they are arguably more of a threat than they are an opportunity. Because the capacity of local electricity grids is finite, only a limited number of EVs can charge simultaneously within a given area without overloading the network. When, where, and to what extent any problems will actually occur is yet unclear. The capacity and quality of local grids varies throughout the country, and the rate of adoption of EVs is also likely to vary between cities and neighborhoods. For grid operators, therefore, it is important to learn about the potential impact of EV charging on the grid and about possible strategies for avoiding grid overload. Whereas electricity producers hope to influence charging behavior through price incentives, grid operators (who are not allowed to sell electricity) aim for a top-down approach in which a smart grid decides which cars are to be charged and how fast this can be done. One alternative to such 'smart-charging' systems would be to reinforce the grid in order to allow virtually unlimited numbers of EVs to charge simultaneously. This option, however, is likely to cost billions of euros.

In order to learn about EVs, their interaction with the grid and, ultimately, about the need for grid reinforcements or smart-charging systems, the majority of grid operators founded an association: E-Laad. Their goal was to establish an initial charging infrastructure in the public domain. E-Laad has installed 2,000 charging stations in response to requests from municipalities and EV drivers.

The individual expectations that these firms hold about EVs are not necessarily positive. It is widely acknowledged by these firms that further technological improvements are necessary and that the market for EVs will be limited at least the coming one or two decades. They point to the role of the automotive industry (will they invest in larger production volumes?), the role of government (how will regulation develop and will incentives for consumers remain?), and the role of consumers (will they accept the limitations of EVs?) to indicate that developments are highly uncertain.

Underlying the differences in strategies is also the question where the regulated domain ends and hence where the commercial domain begins. Grid operators are responsible for all installations up to the ‘meter box’ and they want to make sure that they remain responsible for EV infrastructures in the same way: half way up the recharging pole. Other companies, and not only the traditional electricity suppliers, aim to liberalize (and commercialize) as much as possible with regard to the infrastructure. When successful, they will be able to compete on the basis of network density (and roaming tariffs) instead of just on the costs of their service models (when all poles would be in the regulated domain of the grid operators).

4.3. Conflicts of interests between producers and grid operators

Both actor groups have their strategic rationales for joining the EV niche. These are however not perfectly aligned and in fact, there are two major issues in which their interests are conflicting and which resulting in conflict actor strategies in terms of trying to shape the emerging system.

Division of tasks between electricity producers and grid operators. The most prominent issue in the early stages of the Dutch transition toward electric mobility is the division of tasks between grid operators and electricity producers. Both of these actors aspire to build and operate at least some part of the public recharging infrastructure. Grid operators propose setting up the infrastructure and operating it in order to be able to manage EV charging at the local grid level. Given that they are not allowed to sell electricity, another party would be needed to provide services to EV drivers. If grid operators were allowed to build and operate the infrastructure as part of their regulated task domain, it would be necessary to pass on the associated costs through regular grid-connection fees. This would thus imply the socialization of these grids, whereby everyone (including non-EV-drivers) would pay for the infrastructure. According to grid operators, one argument in favor of such socialization is that it would allow them to develop a smart infrastructure that would decrease the need for general reinforcements of the grid, thus potentially saving billions of euros in the long run. The operators also argue that it would be easier to realize interoperability and roaming between the various service providers if they were to be allowed to manage the hardware.

In contrast, electricity producers propose developing a more commercially oriented infrastructure. Such an infrastructure could then be part of a wider service package (e.g., including home charging) that they could offer to their customers. With this solution, the costs of the infrastructure would be borne largely by EV drivers. Moreover, if each electricity producer (or any other service provider in this respect) were to establish its own network, more competition could result, as this would allow them to compete according to network density. Similar to the competing networks for mobile phones, such competition could accelerate the development of a charging infrastructure and, eventually, reduce costs. Despite the potential benefits of network-based competition, all actors agree that interoperability between the networks is a must and that it is necessary to agree on a model that allows roaming.

In June 2012, the Ministry of Economic Affairs announced that grid operators would not be allowed to include the costs of EV infrastructure in their regular connection tariffs, thus implying that other actors would have to take over their role in establishing the public recharging infrastructure.[2] Nevertheless, electricity producers are reluctant to invest in public infrastructure (due to the lack of a clear business case), and they are likely to focus instead on providing services to homeowners and businesses that would like to charge their EVs on private grounds. Given the producers' reluctance to invest in the infrastructure, it is likely that any future public recharging infrastructure would have to be funded (at least in part) by local or national governments. The initial costs would thus be socialized anyway. In later stages, if EVs are adopted on a large scale and if a sound business model emerges, it is quite likely that local governments would actually recoup these investments.

A related issue involves the legal status of charging points and charging-service providers. A service provider that deals with the end customer currently needs a permit to sell electricity. A legislative change to this situation might be necessary in order to open up competition in the future. Such a change could entail passing a specific set of rules for these types of providers or redefining such services as 'selling mobility rather than electricity' (Ministerie van Economische Zaken 2012, p.68). In addition, current charging points are treated as separate connections to the grid. Owners pay for these connections, and charging points must be equipped with standard panel board for metering (which is redundant, given that all charging stations already contain meters that are more advanced). These costs could be reduced significantly by clustering several charging stations and treating one cluster as a single connection.

Influencing charging behavior. For several reasons, both grid operators and electricity producers strive to introduce some form of controlled or managed charging in the EV system. At the macro level, it is necessary to balance the supply of and demand for electricity, and excessive peaks in demand are undesirable to electricity producers. Furthermore, some form of managed charging would be necessary in order to utilize the potential of EVs as buffers for sustainable energy. Grid operators are more concerned with the micro level of the grid, and they seek to avoid high peaks in demand on a local scale. The interests of these actors do not always align with each other. In times of excess

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//www.agentschapnl.nl/nieuws/rolverdeling-en-afbakening-uitrol-laadinfrastructuur-helder (last accessed: February 13, 2013) electricity from renewable sources, it would be in the producers' interest to charge as many cars as possible. Because simultaneous charging could cause an overload of local grids, however, it would not be in the interest of grid operators. Careful planning and coordination is therefore necessary.

As explained before, current regulations allow grid operators to steer charging behavior through top-down approaches, in which the grid decides who may charge a car and who may not. In the future, depending upon regulatory changes, grid operators might be able to vary their electricity transport tariffs (which are passed on to drivers by the charging-service provider) in order to influence charging behavior. Likewise, electricity providers might be able to use differentiated kWh prices to influence charging behavior.

Dynamic pricing is acceptable to the other actors, who believe that customers will be sensitive to financial incentives and adjust their charging behavior accordingly. As noted by the actors that were interviewed, however, drivers should always have the final say in their charging behavior, and they should always have the possibility of charging whenever they wish. A more rigid form of controlled charging (such as that proposed by some grid operators) would therefore be unacceptable to the majority of actors.

5. Analysis: strategic rationales of niche actors

From the discussion above on the strategic rationales of the electricity producers and grid operators, nine strategic rationales can be distilled. These rationales result from actors' interests and their expectations with regard to the emerging system.

Marketing. Some actors might join niche activities only for marketing purposes and to showcase their 'efforts' in terms of sustainable innovation. Such a rationale can be expected to be based on highly positive collective expectations, but less positive individual expectations of the transition in relation to the actor's interests. This would be the case when an actor simply does not think the transition will ever be a success or that a successful transition does not bring about any opportunities to the actor itself. In the EV case for instance, it could be that electricity producers do hold high expectation of EVs as such, but don't see a commercially viable business model for themselves. Indeed, some of the interviewed grid operators suggested that the EV-related activities of the grid operators were part of their marketing program, while their own efforts were paid for with 'real' R&D money. From the perspective of the niche, pure marketing strategies of actors may very well contribute to the niche in a rhetorical sense ('company A is also working on it'). On the long run one could however suspect that such uncommitted actors are merely detrimental to the cause.

Social responsibility. Although many (corporate) social responsibility activities are often regarded as elements in a marketing strategy, one cannot rule out that (commercial) actors truly care about a number of societal and environmental issues and that sustainability is indeed a core value of an organization. Analytically and empirically, such a rational is difficult, if not impossible, to distinguish from more cynical marketing strategies.

Adapting to regulations. Incumbent actors in an industry can be expected to join a niche in order to be able to comply with future environmental regulations. Since such regulations generally do not prescribe specific technological solutions, some positive individual expectations of the transition can be expected to play a role in the actor's decision to follow that specific path. Furthermore, collective expectations within an industry are likely to be influential as well since some level of coordination between the actors is needed. This rationale is most clearly visible in the automotive industry itself. Even though not all car manufacturers necessarily share high expectations of battery electric EVs, there is broad agreement that electric-drive vehicles are somehow part of the answer to increasingly stringent emission regulations. What is also clear is that these efforts of the car makers, as inspired by current and future regulations, provide a rich source of expectations among other actors.

Developing new business. Existing organizations may seek to diversify their activities and aim to develop new business opportunities. Both actor groups in the electricity industry can be said to have embraced such a rationale. The electricity producers see some opportunities to sell more electricity, grid operators see opportunities to expand their regulated tasks and possibly also to expand their (commercial) consultancy activities for instance. Newly formed organizations may be focused exclusively on the opportunities that are created by the transition. These are the typical niche actors that transition scholars have embraced: entrepreneurs that act as agents of change and that have the fulfilment of the transition as their only objective and interest. In the case of EVs, some of the charging equipment manufacturers and operators are solely founded with such an objective. There interests are thus fully aligned with the transition.

Learning about opportunities. Since transitions are fundamentally uncertain in all sorts of ways, learning is by definition a key element of niche dynamics. Learning can however also be formulated as an explicit objective of niche actors; actors join a niche in order to learn about the opportunities that the transition may present to them. Such an objective reveals a level of uncertainty (e.g. actors are aware of what they don't know yet) and it also reveals, or at least suggests, that their commitment to the niche is conditional. Their support might end when they find out that there is nothing to gain from the transition. The electricity producers for instance recognize several opportunities (e.g. market expansion, increasing customer loyalty, and buffering of intermittent renewable electricity) but the extent to which these opportunities can actually be realized and whether these are significant to the company as a whole is very uncertain. In case they learn, from their niche activities, that the opportunities are too small or non-existent, they could very well withdraw their support. The same goes more or less for the grid operators, as soon as they find out that cars cannot be used to balance local grids (their primary interest) they are likely to end their investments.

Learning about threats. Paradoxically, potentially negative interests in an emerging socio-technical system may be a strong incentive to join a niche. Actors may join a niche to learn about the actual negative impact a transition could have on their interests. Here again, niche membership of the actor is conditional. The actor is willing to join the niche and to invest in developments, but when it turns out that the transition would indeed have a significantly negative impact on its interests, it is likely to withdraw its support. Especially the grid operators seem to act from such a rationale. They are among the most vocal supporters of EVs in the Netherlands and have taken the internationally unprecedented initiative to realize a national recharging infrastructure. But most of this is supposed to learn about potential negative impacts (and strategies to mitigate these impacts as will be discussed in the following strategic rationale).

Influencing the configuration of the emerging system. As stressed before, actor interests relate not so much to a transition as such, but rather to specific configurations of the emerging system. The various design options that are available, technologically, organizationally, and institutionally, present opportunities and threats to the actors and actors thus join a niche to be able to influence the configuration according to their preferences and the specific configurations that they expect to be most beneficial to their organization. They may strive to influence the eventual configuration by simply doing things 'their way' and thereby to de-facto shape the system. They may also join the niche to be able to influence other actors, including governments. The grid-operators have followed both routes. By installing charging equipment that have made sure that they had a say in the choice of location, equipment, and communication protocols. At the same time, they have made sure that they are heard by others and that they can voice their concerns and plead their solutions towards others.

Influencing the configuration of an existing system. This final strategic rationale is not related directly to the transition itself, but can be one of the reasons for actors to join a niche. Actors can use the rise of a new technological option to raise awareness about issues in an existing system. The introduction of EVs, and the collective expectations that circulate widely, creates opportunities for various actors to redefine their roles and to renegotiate some of the existing institutions in the electricity system. For instance, it is suggested that, the grid operators' efforts are partly meant to redefine their regulated tasks and to broaden the definition of 'the grid'; where does the grid end and does the customer connection start? Also, electricity producers would like to be able to charge more flexible electricity rates. Currently they can only offer day and night tariffs and the introduction of EVs provides an additional argument to plead for more flexible tariffs.

6. Conclusions

In this paper, I have tried to explain why and how two groups of actors have joined the technological niche concerning electric vehicles. To explain their strategic rationales, I have elaborated their underlying interests and expectations in relation to the emerging EV system. I have also taken into account the efforts of these actors to influence the technological, organizational, and institutional design of the EV system, as well as the potential conflicts of interest that might hamper the ongoing transition. Although both actor groups differ in their rationales behind their support, one major common reason for engaging in the development of EVs and their recharging infrastructure can be found in the current (and even more so in expected) regulatory pressure on the automotive industry. This pressure is pushing car manufacturers to develop EVs (or plug-in hybrids), thereby posing several opportunities and threats to the actors in the electricity sector. These actors respond strategically by joining the niche for several reasons. Most importantly, they join the niche in order to learn about opportunities and threats. The participation of local grid operators is the most striking example of such a strategy. Paradoxically, these actors are among the most active, even though they perceive EVs primarily as a threat rather than as an opportunity. In this regard, the analysis thus shows that direct positive interests in the success of an emerging technology are not the only source of motivation for actors to participate in a niche, as suggested in the literature on socio-technical transitions. Rather, it is about learning (i.e. testing to what extent their expectations are 'realistic') and it is ultimately about being able to steer developments according to their interests.

This early phase of the transition can be understood as a relatively carefree phase, but support from some of the actors is in fact conditional. In general the actors voiced positive expectations regarding the success of EVs, and they did not seem concerned about short-term returns on investments or about any negative long-term impact. Over time, in case the transition becomes more 'serious', it is likely that actors will start to care about the impact on their interests. If the actual pace of the transition falls below their expectations, some actors might withdraw their support out of disappointment, or simply because their resources are limited. If the pace of the transition exceeds their expectations, a number of actors might start to care as well. These are the actors who have a stake in the current regime and who are not yet willing to give up those stakes. Most importantly however, actor support is conditional on the technological, organizational, and institutional configuration of the emerging system. As soon as it becomes clear that their interests are not taken into account satisfyingly, they might very well end their support. For instance, grid operators may do so when they are not allowed to steer charging behavior to safeguard grid stability.

In contrast to other case studies in the transitions literature, active hindering of the transition by incumbent actors does not seem to be an issue in this specific case. Still, there is a clear difference between actors who are prepared to go ‘all in’ for the development and commercialization of EVs (e.g. start-up firms that produce recharging equipment) and actors who prefer to spend relatively few resources on it, in comparison to the development of their current core business (e.g. the electricity producers and the majority of car manufacturers). Such a reserved approached to supporting or joining a niche fits with the majority of strategic rationales that I distinguished in Section 5. Only a handful of actors really go ‘all-in’ and these are typically small businesses that can be said to rely on protection from others rather than providing (financial) protection to the emerging system themselves. That is not to say however that these actors cannot contribute to the niche. In fact, start-up firms like EV manufacturer Tesla or battery-switching station developer Better Place are very important in terms of raising expectations and underpinning existing storylines by showing real-life, but not necessarily commercially viable, solutions to often referred to challenges.

Finally, the analysis presented in this paper uncovers two specific challenges for the governance of transitions. On the basis of the aforementioned dichotomy between proponents and opponents of a transition, it is tempting to think about transition policy in terms of carrots and sticks. The carrots are presented to the typical niche actors and the sticks are used to push the incumbent regime actors to join in. What is needed however is more attention to the role of actors that are somewhere between these categories. These actors support the transition conditionally, and there might be a role to play for governments to provide the right conditions, but also to mediate between the various actors and their, sometimes diverging, interests in specific configurations of the emerging system. At the same time, some form of stick policy may be necessary in the end to push these actors to continue their contribution to the niche, even though the emerging system is not entirely aligned with their interests. The legitimation of such policies would however be challenging, as these would be explicitly technology-specific. Furthermore, many of the necessary actors (e.g., grid operators and electricity producers) are currently not part of the transportation system, and they can therefore not be held responsible for its decarbonization.

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Session 6: Transitions in the agro-food domain

Noisy Summer in France. The Ecophyto 2018 Plan as a tool for establishing a transition regime?

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Introduction and Research question

Over the past decade there has been a revival of interest in research on technological change (Rip and Kemp, 1998), with a particular focus on sociotechnical transitions (Geels , 2002, 2004; Elzen et al., 2004)) related to the major expectations that sustainable development objectives give rise to in many sectors of the economy (Smith et al., 2005; Geels, 2010). Various representations of these changes are proposed, notably those that emphasize the need for reflexivity by the actors and stakeholders (Voß, Bauknecht, and Kemp, 2006)[1] and for a transgression in the political use of scientific knowledge (Hoppe, 2005).

We are witnessing a multiplication of niche innovations and a steady increase of discourse and regulations on the national and international institutional scene (Cash, Clark et al., 2003). Studies on transition governance consequently often stress the need to allow for the alignment of innovation niches in established regimes (Schot and Geels, 2008); or alternatively to structure the specific regimes instituting these niches into entirely new regimes, linking up new modes of production and new modes of consumption, essentially by way of standards (Loconto and Bush, 2010; Loconto and Barbier, 2012). Many authors note however that such changes can be difficult to achieve due to the effects of lock-in of sociotechnical regimes (Vanloqueren and Baret, 2009; Egyedi and Spirco, 2011). It follows that the actors of change need to develop a political vision and to maintain a firm purpose;

[1] Voß and Kemp (2006) suggest that “the reflexivity of governance also includes the possibility that certain governance patterns undermine themselves by inducing changes in the world that then affect their own working” (p. 4);

and those who 'observe' them need to question the design of the *dispositifs* through which new possibilities are opened, and thus to study the actual practices of transition management (Grin, 2006; Shove and Walker, 2007).

Studies on transitions draw on cases in the past, where regime transitions have taken place. From an analytical point of view, they therefore benefit from an interpretation with hindsight, when the "end of the story" is known (Geels, 2010). As many recent studies have pointed out, seeking to make a transition process "in the making" explicit involves methodological difficulties in grasping both an orientation towards the integration of diverse possibilities, and an ability to effect arrangements that is performative (Stirling, 2011). It is necessary to take into account: (1) learning and reconfigurations of discourses and conceptions, (2) the elaboration and stabilization of new technical practices, and (3) the reconfiguration of rules via means of coordination that produce change. This level of observation seems important for the study of transitions. It enables us to enhance and flesh out reflection on the conditions governing the shift from one step to the next in the transition process, and to get to the core of the analysis of all the dimensions constituting a regime change, by following its pathways (Geels and Schot, 2007).

Our research focuses on agriculture in industrialized countries. In Europe and throughout the rest of the world this sector is facing the need to function more ecologically (Cerf et al., 2000) and to address criticism for being a "treadmill of production" (Barbier, 2010). A synthesis of a number of empirical studies on these issues peculiar to transitions in this productive sector is already underway (Darnhofer et al., 2012; Barbier and Elzen, 2012), notably on the question of changes to crop protection strategies (Ricci et al., 2011). A significant body of work on the agricultural sector has stressed the importance of simultaneously addressing specific public policies concerning ecologization, and the technological and economic shifts, and management of promises, accompanying them. Yet this articulation is no foregone conclusion, especially in light of the fact that the sector is characterized by a proliferation of initiatives indicating a form of progress characterized by plurality and diversity (Stirling, 2011).

In this paper we focus essentially on the emergence and implementation of a public policy instrument and other types of *dispositif* (Barbier, 2008) designed to promote significant change in agricultural development and here especially with crop protection practices. The instrument stems from a European regulation under Directive 2009/128/CE[2] defining a general framework and obligations pertaining to a reduction of the use of phyto-sanitary products and to change crop protection strategies (Ricci et al., 2011). Our empirical work is situated in France, where we have studied the implementation of a national plan corresponding to the directive: ECOPHYTO 2018 (see appendix 1). The plan is dedicated to training, incentives and control aimed at a 50% reduction in the use of pesticides in France's agriculture and green areas by 2018.

We examine the design and implementation of this plan by seeing it as the result of a progressive framing of pesticide reduction as a public issue, based on the indexing of pesticide use as a collective risk: a food risk (presence of pesticides in foods), an environmental risk (effect of pesticides on the ecology of agri-eco-systems and water resources) and a sanitary risk (risk for the users of pesticides and for people living close to the fields treated with pesticides). We can posit that this national plan

[2] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:309:0071:0086:FR:PDF

is designed to facilitate a transition towards more sustainable agriculture, given the political sensitivity of the politicization of these risks. This sensitivity is primarily due to the largely constructed ignorance as to the prevalence of professional risks (Boudia and Jas, 2007; Jouzel et Dedieu, 2013) but also to the difficulties for change agent to face sustainable goals and inner tensions of the practitioners they have to accompany (Cerf et al. 2010).

Our aim in undertaking this collective observation and longitudinal monitoring of the ECOPHYTO 2018 plan, is to answer the following research question: does the implementation of the plan allow for the establishment of a “transition regime” that: (i) makes significant large-scale changes possible in so-called conventional agriculture, and (ii) allows for the emergence of new arrangements to establish niche agricultures in the framework of greater recognition of their sustainability (e.g. organic farming, small farms, ecologically intensive farming)?

Theory /conceptual framework applied

Our approach consists in examining the dynamics of change as they play out in the construction and implementation of the ECOPHYTO 2018 plan (from a diachronic point of view), and the variations of this implementation in situations of collective action in rural territories or supply chains. We draw on a multidisciplinary analysis combining socio-historical approaches to public policy and collective Action. We relay on an approach that focused on the activities of intermediaries working at the interface between the niches and the socio-technical regime, and on an approach, which is centred on the study of situated design processes – i.e. anchored in systems of activities- with a view to investigating the implications of changes in practices. This middle-range approach (Geels, 2007) that we try to explore in the agricultural sector (Barbier et al., 2011) aims to understand the instruments of public policy are designed, created and applied in order to induce transition, and how they evolve over time in relation to the obstacles, the sociotechnical and professional experiments, and the habitus of the actors they encounter. In this way we seek to ensure that public policy is not interpreted from a strictly political point of view only (Lascoumes et le Gallès, 2004). Instead, we wish to understand how the demand for transition “reworks” these instruments, reshaping them and changing the content to some extent. In this respect it is essential to clearly understand the wide variety of existing agricultural technologies. Some involve the withdrawal of ancestral techniques such as labour (Goulet and Vinck, 2012), while others call for organic solutions associated with lessons drawn from experience and granted increasingly more consideration by research as the agri-ecological stream emerges (Lamine, 2011). If there are transformative capabilities in this wide range of techniques, they play out in tandem with the adaptive capabilities or, on the contrary, with the lock-in peculiar to this sector which is rich in a wide variety of institutions. As Dolota (2009) explains: “*The specific interplay between the two influencing factors* [niches and landscape] *creates distinguishable modes of sectoral transformation, ranging from anticipative and smooth adjustments to reactive and crisis-ridden patterns of change. Even processes of radical sectoral change continue over longer periods of mismatch and are characterized by numerous and mostly gradual organizational, structural and institutional transformations”*.

The study of these organizational, structural and institutional, as well as technological, transformations is therefore of particular importance in our research because they are at work in multiple ways, depending on diverse action logics. Not only do the logics of agricultural supply chains (grain, fruit, vegetables, etc.) have their own particular characteristics, they also vary profoundly in relation to the territories and their alignment with quality standards. Our intention is to understand these transformations and the changes of practices to which they lead, with all their variety. We posit that the instruments designed to perform change are diverse and multiple, and that the sector affected is likewise characterized by diversity. That is why, over and above the analysis of public policy instruments and their evolution, we consider it necessary to understand the activities of intermediation that contribute to building this interface between public policy instruments and local situations. This is all the more necessary as these situations are already caught in the dynamics of change aimed at translating a demand for ecologization into technical practices and systems of sustainable production (Elzen et al., 2012), before the arrival of recommendations based on a directive on pesticides. This intermediation is analysed in local situations, in two respects. First, we seek to account for situated design processes encompassing the exploration of new sustainable agricultural systems and the mobilization of the instruments of public policy. Second, we seek to understand the processes of generalization and institutionalization (up-scaling and out-scaling) of these local explorations, and the way in which these processes participate in the transformation of public policy instruments.

Methods

The method used is qualitative data analysis, combining data collection, surveys and observation, but also reflection outsources from collaborative design studies. To reconstruct the process of design and creation of the ECOPHYTO plan and its evolution since then (see appendix 3) , we draw on (i) written sources, (ii) semi-structured interviews with the actors concerned by the design of public policy tools (administrative agents, experts, scientists, etc.) and by their local implementation (chamber of agricultural advisors, agricultural coops, farmers, etc.), and (iii) participant observation during our involvement in the various expert committees associated with the construction and evaluation of this plan, and in our reading assisted by text search techniques on mainly online databases. The written sources are of two kinds: those produced by the protagonists themselves, who leave traces of their own action (Farge, 1989), such as the minutes of meetings or institutional reports; and those constituted by comments on the process of elaboration and implementation of the ECOPHYTO plan: press reviews, mostly from the national press, and experts' reports such as the ECOPHYTO R&D Report to which several authors of this article contributed.

To study the process of situated design or the work of intermediation, we have held interviews with the agents involved in design or intermediation work. We have also been involved in local situations through participant observation or by accompanying these processes and this work ourselves. In particular, we propose spaces for reflection on the intermediation work, and approaches in which agricultural systems that meet territorial challenges can be designed, with the twofold requirement of a broad exploration of possibilities, and directly operational propositions (Prost et al. 2007).

Mid-term results

After two years of empirical research on the ECOPHYTO 2018 plan and its various *dispositifs*, and based on earlier work on the dynamics of change in industrial agriculture (Cerf et al., 2000; Barbier 2008; etc.), we are starting to have a collection of intermediary results that we can used to answer our main research question.

1. In France the *Grenelle de l'Environnement* was an event that affirmed the desire to embark on a process of transition in various sectors, for which specific policies were subsequently adopted. This institutional and participatory political operation was designed to clarify the public policies that would be required to support sustainable development and the ecologization of certain sectors (building, transport, agriculture, energy). In the agricultural sector the Grenelle resulted in a set of recommendations, for instance for a moratorium on GMOs, for more use of organic farming products in school canteens, and for the reduction of pesticides by 50% throughout the country between 2008 and 2018, under the ECOPHYTO plan. This plan, designed to guide the transition, was built as a process of 'non-alignment'. It established de facto a separation between, on the one hand, initiatives taken within the agricultural sector, which could contribute to reducing the consumption of pesticides, and, on the other hand, the logics of government authorities guided essentially by the fact that media and environmentalist advocacy had put risks relating to the use of pesticides on the political agenda. The purpose of the plan was not devised with and by the actors of the agricultural world, even though some had been exploring and experimenting for a long time already with alternatives to the use of pesticides and with forms of agriculture that reduced or banned their use (organic farming, economic and autonomous farming, integrated production, ecologically intensive farming, conservation farming). In other words, the plan was not based on a diagnosis seeking to achieve coherence on a country-wide scale between forms of agriculture that used little or no pesticides. Nor was it based on an integrated diagnosis of the various risks associated with pesticides (sanitary, professional, food and environmental). Our observations and field studies show that the quantified objective of a 50% reduction in ten years was the result of a decision process that translated into a global figure the state of a particular balance of power between ecologist organizations, farmers' unions, and the government, at the time of the *Grenelle de l'Environnement*. It thus emerges that the announcement of the ECOPHYTO plan linked to the precise political moment of the *Grenelle* stems from a fairly classical logic, on the institutional and political scene, of announcing general objectives.

> Result 1: The plan resulted in a series of actions aimed at articulating the requirements of the European directive and the obligations of Member States with government action conceived of as the result of a societal power struggle. Hence, it was not seen as a statement of possibilities and constraints as identified in the agricultural world after at least two decades of circumventing the Nitrate directive and concomitant experiments to establish niches as well as experiments with sustainable production systems.

2. The goal of sustainable development is reflected in global objectives of "reduced use" rather than the banning the products concerned. By envisaging an overall reduction "on a country-wide scale",

policy makers in France left numerous possibilities open for defining this goal and thus for managing the risks associated with using pesticides or not using them. The documents and the debates that took place in the period when this goal had to be translated into a political framework of reference show that the actors of the agricultural world rapidly took up the framework and proposed a variety of versions. For instance, an expert report drawn up prior to the implementation of the ECOPHYTO plan, called "ECOPHYTO R&D" (appendix 2), mobilized many different actors in the agricultural world in relation to the first inter-ministerial plan of reducing pesticide risks. It largely contributed to establishing the reference framework by focusing essentially on environmental risks. Above all, it studied the possibility of effectively reducing environmental harmful effects of pesticide uses by having cut 50% of the global volume of phyto-sanitary products by the end of 2018. The report was based on a diagnosis of the current situation of pesticide use, and proposed scenarios for identifying the implications of meeting the objectives in terms of possible combinations of different changes of practices in crop sequencing and technical itineraries, in a variety of agricultural contexts. In particular, it has introduced the use of an environmental risk indicator towards the spray of pesticides, the IFT (*Indicateur de Fréquence de Traitement,* says Indicator of Spraying Frequency*).* This indicator, which has been proposed after the Danish experience (Gravesen, 2003) and its enlargement to Northern countries of Europe (PAN, 2004), is recognised by the French Ministry of agriculture as one the key evaluation system to measure reduction of uses (Champeaux, 2006), in relation with both OCDE policy-making forum (Pingault, 2007) and compliance to the European strategy of sustainable agriculture under a specific reduction plan (PIRRP 2006-2009, Inter-ministerial plan to reduce pesticides risks). This indicator can serve, on any kind of farm, to simply and operationally evaluate the reduction of the pressure exerted by pesticides on the environment, by relating it to the number of sprays. In parallel, other actors - mainly agricultural coops that distributed phytosanitary products and advised farmers- emphasized the technical and economic risks of limiting pesticides, in terms of lower yields and lower profits. And others highlighted the health hazards of workers, closely related to spraying equipment and to certification. They challenged the objectives while affirming their commitment to change, highlighting the margins for optimization of current use of pesticides and fertilizers via the development of decision aid tools, low-volume techniques, improvement of the functioning of spreaders, organisation of pesticides tanks recycling chain, and by proposing measures to protect farm workers.

Result 2: The ECOPHYTO plan has been repeated in the agricultural sector largely on the basis of prior collective expertise reflecting a technological orientation towards possible combinations of different more or less radical changes of practices for productive systems. Environmental risk is thus addressed essentially under the constraint of technical and economic risk.

3. The public policies adopted consequently reflect a segmented approach to the various issues identified. The ECOPHYTO plan translates into Key Actions which may consist of instruments designed to treat the various pesticide-related risks for human health, plant cover, natural resources, and the environment. Or they may be designed to help not only farmers but also agricultural advisers to embark on the transformation of their practices, starting with various experimental *dispositifs* whose specific governance is a matter of tense negotiations. Ultimately, the plan presents as a fairly complex set of: (i) recycled ideas, in the sense of March (1991), (ii) opportunities aimed at protecting the public authorities from nascent controversies, and (iii) real innovations in experimental policy

tools, yet which have hardly been considered for integration into the existing *dispositifs* of sustainable development, and have generated controversy on the general design of this mode of intervention. The implementation of the ECOPHYTO plan reflects some difficulty in applying the classical frameworks of risk assessment and management in the context of public policy applied to a sector as fragmented and diversified as agriculture. Although this difficulty is understandable, the plan does not provide for a systemic approach to addressing the various risks associated with the use - or non-use- of pesticides. Nor does it suggest technical changes and consequent changes in competencies that might be required.

4. For example, the fifth objective of the ECOPOHYTO plan (Improving the monitoring of plant pests with a view to targeting the use of pesticides) is not really based on a renewed conception of risk management associated with plant health or pest control in agriculture. It reflects the “recycling” of an old information system, based on a Agricultural Monitoring Bulletin, hitherto carried out by the Crop Protection Direction in the framework of the prerogatives of the National and regional administration services of the Ministry of agriculture. Rather than renewing conceptions of risk management for crops, our fieldwork showed that the challenge was above all to transfer the principles of plant surveillance to public-private or professional organisation, based on a logic of delegation of services by mandate. Hence, few changes were made in terms of objectives though the institutional framework clearly changed. Two examples illustrate this. First, a survey carried out in a specific territory showed that the new “plant health bulletin”, the BSV *(bulletin de santé du vegetal- says, Crop Health Bulletin)*, (within the Objective 5 of ECOPHYTO), was taken into consideration by a small proportion of farmers, namely those who were already the most committed to applying agronomic knowledge. The majority were disinterested in the BSV, preferring to rely on the judgement of their regular advisers, mainly from the coops, and who were responsible for selling the coops’ products. These advisers proved to be reluctant to engage in the BSV approach, which forced them to pool their information and to practise a certain degree of transparency on their diagnosis of crop systems. In the case of advisers working at the chambers of agriculture, the BSV was sometimes seen as an opportunity to revive the link with the “essence” of their profession, agricultural extension services, in so far as this work afforded an opportunity to discuss thresholds and indicators to apply in deciding when to treat crops. Their participation was thus an opportunity to become aware of the broadening of their audience towards actors, local authorities or natural resource managers (e.g. water managers) and the position that they were therefore led to occupy at the interface between different actors. This called into question their role as farmers’ advisers.

In another example, the public authorities did not initially provide for Objective 9 concerning the health and protection of workers; it was added at the last minute at the request of representatives of the phytosanitary chemical industry (IUPP). This may seem paradoxical, but a strategic analysis of the system of actors shows that their request was closely linked to the then emergent controversies on occupational intoxication by pesticides and a highly charged context due to the legal proceedings instituted by a farmer against Monsanto, which he blamed for his occupational disease[3]. More broadly speaking, Objective 9 did not directly address the way in which pesticide-related professional hazards were actually treated by the clinicians, the agriculture health insurance company and the

[3] The farmer was Paul François, who was poisoned by the insecticide Lasso in 2004. In 2008 he sued the company Monsanto which he claimed had failed to fulfil its “obligation to inform”.

administration of Public Health. Our research shows that the absence of epidemiological data to support a new approach to these risks was largely the result of a socially constructed ignorance (Jouzel and Dedieu, 2013). Finally, Objective 2 (consisting primarily of establishing a network of 2,000 farms, in 200 groups of farmers accompanied by an adviser) shows a form of innovative public policy and risk management tool. It can be seen as a space for learning and institutionalization of forms of agriculture to reduce the use of pesticides as they had already been experimented with, to a greater or lesser degree, in agriculture. The choice of using the IFT as an indicator of environmental pressure, rather than precise indicators on environmental risk dealing with impacts on natural milieu or human health, can be seen as an adaptation by the sector to risk assessment and management concerning the use of pesticides.

> Result 3: The local implementation of the various actions took place in a segmented way and reflects above all the adaptive and absorptive capacities of the prevailing neo-corporatist regime, rather than its ability to support the experiments and changes already under way locally. We can posit that the absence of systemic risk management associated with the use or not of pesticides adds to this weak entrainment effect of the ECOPHYTO plan in a process of transition. It is likely not to exceed a rather marginal improvement of technical and economic effectiveness and a respect for good practices in pesticide use.

4. When we closely examine the modalities of local take-up of actions of the ECOPHYTO plan that explicitly propose forms of collective experimentation, we see that very few new rules of coordination are made to articulate these experiments to "usual" development actions. Our research included a survey on agricultural advisers and farmers involved in the implementation of the FERME network on the scale of a Region (Objective 2 of the ECOPHYTO plan), along with interviews with various individuals on committees at national level for facilitating and steering the plan. Our findings show a form of crystallization of attention on the way in which the network can provide references on systems reducing the use of pesticides, thus leaving unanswered the question of how the dynamics of change on farms, and more broadly, whole territories, can be accompanied. The intermediation work and the coordination established partially reproduce the classical forms of relationship between the actors of research, R&D and advisory services, to the detriment of an approach centred on learning and the accompaniment of sustainable changes of practices.

A more detailed analysis of the work of intermediation under way highlights the absence of cognitive resources enabling the various actors of the territory to resituate changes in agricultural practices in the context of local issues, and thus to see public policy instruments as levers accompanying local dynamics. The implementation of Objective 2 (DEPHY Network) at local level, as witnessed in one specific Region, enabled us to identify the existence of coordination within this network, between the local and the national levels, to define the modalities of the collection and application of data on farms, in particular. The network managers see this as a means for proposing cognitive and symbolic resources to advisers engaged locally in accompanying change. Yet these resources are not being concretized, and until now have proved to have little efficacy in revealing local dynamics of support for change that go further than pre-existing ones. In other territories where the reduction of pesticide use is related to issues on water quality, local advisers and facilitators make do with the regular repertoires of action that they habitually use (Cerf et al., 2012). But these repertoires are proving to be inappropriate for addressing the socio-political and socio-cognitive dimensions of the challenges identified nationally by the ECOPHYTO plan. Analysis of the situation suggests that it is difficult to find resources to develop new forms of coordination, not only with a wider diversity of farmers but also with other actors of the territory (those who drink water, local and regional authorities, water utilities, cooperatives, etc.). Research-action carried out in a water catchment area shows that it is nevertheless possible to create a collective dynamic of change by facilitating the design of new agricultural systems by the farmers themselves, and at the same time to propose new forms of agri-environmental monitoring (Prost, 2012). But this type of monitoring is not easy to institute because it challenges the types of incentives that the public authorities have recognized until now, for farmers to change their practices in drinking-water catchment areas.

Result 4: Despite the existence of actions intended to support processes of local experimentation in order to meet the goal of halving pesticide use by 2018, new coordination rules and new forms of intermediation are struggling to emerge. There is a need to challenge modes of construction of cognitive resources, along with the lack of attention paid to processes of accompanying learning by all the local actors, in order to articulate technical changes in territorial or supply-chain logics.

Conclusion

The actions taken to institute the ECOPHYTO plan have been transposed onto a reference framework that is both fragmented and highly structured in its various versions: fragmented because, despite the constant reduction of the number of farms, the sector's production remains split into a multitude of very small businesses; and highly structured when we consider its relations with policy and innovation. Compromises in the 1960s between the farmers' representative and the State remain structurally active, over and above the evolution of agricultural policies and innovations in agriculture. The tools developed by the public authorities to accompany change are thus above all largely designed to be re-appropriated by the institutions inherited from a neo-corporatist period. Farmers practising conventional agriculture – who are the large majority in terms of surface areas and volumes of production –lack adequate material and organizational resources and are caught in intense controversy within the agricultural world over the sector's orientations. They consequently function with a twofold logic: a logic of harnessing the constraints and prescriptions of change within a rigid institutional framework, and a logic of supply chains adaptation to link the supply of inputs (and thus of pesticides) with retailing and commercialization functions.

Studying transitions "in the making" enables us to understand changes that are desired or under way not simply as a change of state but, on the contrary, as layers comprising a multitude of constantly evolving "paths" where the take-up of innovations and resistance to them exist side by side. Hence, it seems that the shift from one state to another of the socio-technical regime, or more radical change from one regime to another, takes place according to paths that are strongly framed by or embedded in sectoral logics. The question is then less about a change of state than about the way in which coordinated public action can establish a transition regime characterized by the implementation of a *dispositif* allowing for the exploration and learning of a new type of action. The same type of conclusions have been issued by many French scholars about agri-environemental policy during the past two decades (Busca and Salles, 2001; Mermet, 2005; Steyeart et al., 2007). It seams necessary to get read of the previous agri-environemental cognitive framework and to clearly put procedural effectiveness first, and to elicit the consequences of that orientation (Steyaert and Barbier, 2013) if the objective of pesticide use reduction is an objective and not a matter of tuning the existing agri-chain system.

We have examined here the way in which change to sustainable agriculture is viewed and how little this change is taken-up, so to speak, by conventional agriculture even though it is radically under way in agri-ecological niches. Yet there is a more general question about what this type of transition regime involves. Our research and our first results raise the question of whether the instrument makes it possible to institute change or whether it is not actually a double green-washing weapon: on the one hand it maintains a conventional systems that shows its ability to become greener in its discourse but has difficulty supporting significant change; on the other hand it maintains organic alternatives which provide reassurance and the communicational means to salute a greening under way. But in our opinion it is not enough simply to put forward this critique and to provide the actors with the results of our research.

Even if the concrete implementation of change in the agricultural world seems uncertain, our research has enabled us to see the extent to which the ambitious objective of halving pesticide use has made an impression on all the actors involved, without for all that pointing to new or less recognized forms of transition such as exploration. Hence, it is surprising to see how even those actors most “threatened” in this respect – that is, those who financially depend most on the commercialization of pesticides, such as representatives of the industry (IUPP) – have taken note of this change of regime, at least in their discourse. For sure, technological and political promises are words based on the cognitive reference frameworks of public policy. Yet our first results seem to indicate that achieving a transition regime – that is, with properties of maintenance and support of exploration – requires the creation of a space for life and experience of the world for which the *dispositifs* of governance by instruments of transition are nothing more than props or at best scaffolding destined to disappear.

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Appendix

Appendix 1. Presentation of the plan Ecophyto (http://agriculture.gouv.fr/Ecophyto-in-English-1571)

Following on from the *Grenelle* consultation process on environmental issues in 2008, the Ecophyto plan embodies the commitment given by the authorities, industry professionals, and representatives of civil society – the plan's co-authors – to cut the nationwide use of pesticides by 50% in the space of ten years (2018), if possible.

Ecophyto is then the French action plan to reduce pesticides, in compliance with the Sustainable use directive. The most notable goal of Ecophyto is to reduce the dependency of farms on plant protection products, while at the same time maintaining agricultural production at a high level in both quality and quantity terms.

How?

- by disseminating as widely as possible among users and their advisers information on known techniques for economic use of plant protection products and by improving the information given to farmers in real time on the distribution of crop diseases and pests with a view to improving the targeting of treatment,
- by ensuring that every actor in the chain is fully competent : distributors, advisers and professional users of plant protection products,
- by injecting energy into agricultural research into crops that require less chemi-cal protection and by communicating the results of that research to the widest possible audience

Details about Ecophyto's measures:

In addition to the withdrawal from the market of plant protection products containing the active substances of most concern, the core purpose of the Ecophyto 2018 action plan is to begin immediately to disseminate the best low-pesticide agricultural practice (***Focus 2***) and to drive innovation based on research directed at new systems of production enabling further reductions and which are viable and lend themselves to dissemination (***Focus 3***). Alongside actions for reduced use, the plan's success must involve training and safe pesticide use, these being necessary conditions to be met if these programmes are to win the widest possible acceptance (***Focus 4***). The plan provides for the strengthening of networks for surveillance of bioagressors, to ensure that treatments are properly targeted, along with the undesirable effects of pesticide use on crops and the environment (***Focus 5***). And lastly, due to the specific situations of French overseas departments with regard to the risks associated with plant protection products, one of the plan's core focuses is dedicated entirely to them (***Focus 6***). Since the relevance of reducing the use of plant protection products goes beyond the confines of the agricultural world, one strategic focus of the plan is specifically devoted to the issues surrounding reduced, safe use of pesticides in non-agricultural areas (***Focus 7***). This new challenge is therefore a major one. It represents a very substantial paradigm shift that can be achieved only with the support of all stakeholders, the latter having already been mobilized for the drafting of the present plan. A system for quantitative monitoring of progress on the reduction of pesticide use (***Focus 1***) has been made an integral part of the plan. Specifically, this is based on an indicator (NODU), which is proportional to the number of dosage units represented by sales of active protection substances.

Progress on the plan is tracked nationally and regionally with input from the same partners through a consultation and monitoring body attached to the Ministry of Agriculture (***Focus 8***).

List of focus:

- FOCUS 1 - Evaluation of progress on reduction of pesticide use
- FOCUS 2 - Determination and general dissemination of agricultural systems and known methods conducive to reduced pesticide use through the mobilisation of all partners in research, development and knowledge transfer
- FOCUS 3 - Innovation in the design and development of low-pesticide technical pathways and cropping systems
- FOCUS 4 - Training in reduced, safe pesticide use

- FOCUS 5 - Reinforcement of surveillance networks for bioagressors and the unwanted effects of pesticide use
- FOCUS 6 - Inclusion of the specific features of French overseas departments
- FOCUS 7 - Ensuring reduced, safe use of plant protection products in non-agricultural areas
- FOCUS 8 - Organisation of national monitoring of progress on the plan and its roll-out in the regions, plus communication on the reduced use of plant protection products

Appendix 2. Presentation of the summary of the Expertise Report Ecophyto R&D

1. La méthode d'élaboration et ses limites

1.1. Le cadre commun d'analyse

1.2. Les données disponibles

1.3. Ajustements méthodologiques et limites de l'étude.

2. L'utilisation des pesticides en France en 2006

2.1. La répartition des pesticides selon les productions

2.2. La répartition régionale de l'utilisation des pesticides

3. Analyse des niveaux de rupture à l'échelle parcellaire

3.1. Les grandes cultures

3.2. La Vigne

3.3. L'arboriculture fruitière

3.4. Les cultures légumières

4. Les scénarios de réduction d'usage des pesticides

4.1. Les scénarios de passage complet aux différents niveaux de rupture

4.2. Les scénarios de combinaison de niveaux de rupture en grandes cultures

4.3.Conclusion

5. La diffusion des changements de pratiques : positionnement des acteurs et options pour l'action publique.

5.1. Objectifs et méthodologie

5.2. La diffusion des changements de pratiques : constats et analyse

5.3. Options pour l'action publique

6. Structuration d'un réseau d'acquisition de références et de démonstration

6.1. Inventaire des dispositifs existants

6.2. Analyse des besoins des acteurs et de dispositifs remarquables

6.3. Conception et configuration du dispositif proposé

6.4. Gouvernance et moyens requis pour le dispositif 6.5.

Conclusions

7.Conclusions.

Annexe 3. Timeline of the ECOPHYTO national plan in political context

Phase 1: Before the Plan Ecophyto

2000 : Premier plan interministériel « *pesticides* »

2006 : plan interministériel de « *réduction des risques liés aux pesticides* » (PIRRP)

2007
Juillet à Octobre 2007 : Grenelle de l'environnement –
Octobre 2007 : décision de lancer le plan Ecophyto 2018

Phase 2. Designing the Plan Ecophyto

2008
Ecophyto
22 mai 2008 Travaux du comité opérationnel d'experts sous la présidence de Guy Paillotin
Présentation des conclusions du groupe opérationnel d'experts
10 septembre
Présentation du plan ecophyto 2018 en Conseil des Ministre (voir le communiqué de presse et le compte rendu du Conseil des Ministres)

Société civile
Début du procès de Paul François, agriculteur intoxiqué à l'insecticide « Lasso » en 2004 et qui a lancé en 2008 une procédure en responsabilité civile contre l'entreprise Monsonto où il s'agissait d'un manquement d'établir son « obligation d'information »

2009
Ecophyto
Janvier
Lancement du programme d'expérimentation pour les DOM
22 avril
Premier Comité national d'orientation et de suivi du plan: adoption des fiches actions du plan , préparées dans le cadre du Comité opérationnel présidé par Guy Paillotin
7 juillet
Premier Comité national d'épidémiosurveillance
Septembre 2009
Premiers lycées agricoles engagés dans le plan Ecophyto 2018
Automne 2009
Publication des premiers Bulletins de santé du Végétal
Hiver 2009
Premières formations dans le cadre du Certiphyto expérimental
Premier Comité consultatif de gouvernance pour l'utilisation des crédits issus de la redevance pour pollutions diffuses

Europe
21 octobre
Adoption du Paquet pesticide de l'Union européenne - Décembre 2009

2010
Ecophyto
28 janvier
Colloque de restitution de l'étude Ecophyto R&D
5 février
Première réunion du Comité d'experts , sous la présidence de Jean Boiffin
28 février
Séminaire sur la recherche dans le cadre du plan

11 février
Ecophyto

Sélection des fermes pour le test du réseau de fermes pilotes

Société civile
Création : association des victimes « Phytovictimes »

2 avril
Ecophyto
Signature de l'accord Jardiniers amateurs
Tout au long du 1er semestre
Premières réunions des Comités régionaux d'orientation et de suivi, sous l'autorité du Préfet de région

4 juin

Election du député André Flajolet à la présidence du Comité consultatif de gouvernance du plan Ecophyto 2018
Juin
Lancement de la communication vers les jardiniers amateurs

12 juillet
Lancement de l'appel à candidatures pour le déploiement du réseau fermes pilotes

12 juillet
Adoption de la loi portant engagement national pour l'environnement, dite Grenelle 2 : transposition de nombreux éléments de la directive Utilisation durable des pesticides, en particulier relatifs au certificat et à l'agrément
3 septembre

Signature de l'accord cadre de Professionnel en zone non agricole

28 septembre
Nomination du député Antoine Herth pour une mission parlementaire sur le bio controle
6 octobre
Deuxième Comité national d'orientation et de suivi , publication du rapport Deux ans d'action, de la première note de suivi, et annonce du renforcement du volet protection de l'utilisateur et évaluation des politiques publiques

21 décembre
Prolongation de l'expérimentation du Certiphyto jusqu'au 31 juillet 2011 (Décret n°2010-1611)

2011

Ecophyto
24 janvier
Premier groupe de travail pour définir les actions à mener dans le cadre du plan sur la santé et la sécurité des utilisateurs (axe 9)
19 février
Ecophyto au salon de l'agriculture
24 février
Lancement du réseau de fermes DEPHY de démonstration et d'acquisition de références
Société civile
« Pesticides, notre poison quotidien ? », diffusé le 15 mars 2011 sur Arte

2012

« *La mort est dans le pré* » reportage diffusé le 17 avril 2012 sur France 2.

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Unlocking the full potential of Technological Innovation System and its functions framework – a viewpoint

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Abstract

Many technological innovation system (TIS) studies including those that use a functions approach focus a) on issues of sustainability, like renewable energy technologies, and b) formulate policy recommendations to foster sustainable transition (for an overview see Truffer et al. 2012). However, these policy recommendations often remain relatively unspecific and policy makers are not advised well on how to tackle the complex and often systemic challenges associated with sustainable transitions. Our paper contributes to the ongoing debate about how to improve the translation of TIS research findings for the political sphere. To this end, we try to build bridges to established strands of research outside the 'traditional core' of transition studies by showing ways of enriching TIS functions approach findings with strands of knowledge from related disciplines. Specifically, we aim at increasing the policy relevance of TIS and its functions approach by discussing the potential complementary role of economic theories.

1 Introduction

Technological change is one cornerstone addressing today's environmental challenges. Among other issues, a significant and prompt renunciation from the current path of CO_2 emissions is urgently needed to curtail climate change (Pizer & Popp 2008). In order to direct technological change in its particular speed and direction, policy interventions are often needed to overcome certain barriers, which might hinder a rapid diffusion of the respective technology (Jaffe et al. 2002). Hence, the evaluation of different paths of technology innovation is a necessity question for today's policy makers. The *technological innovation system* (*TIS*) *and functions* framework respond to this by providing a tool to determine the various factors influencing technological innovation and diffusion.

The beauty of the analytical framework provided by the *TIS and functions* approach is its applicability to each singular technology (Carlsson & Stankiewicz 1991). This in turn results in high policy relevance when it comes to the question of how policy could incentivize the diffusion of the specific technology. In addition, the framework reduces the complexity of the considered case while at the same time providing a systemic view of it. The strength of the analytical framework is its *scanner function* by which it identifies systemic weaknesses (Smits & Kuhlmann 2004)– also referred to as bottlenecks (Markard & Truffer 2008; Johnson 2001; Jacobsson & Bergek 2011) in the *TIS*. The bottlenecks serve as starting point for policy recommendations to enhance the innovation and diffusion of a technology and thereby providing a sustainable transition (Bergek et al. 2008). However, based on a review of the existing literature in this field we found that although the *functions* approach is well suited to identify bottlenecks and pinpoint to systemic problems in a *TIS;* so far conclusions on policy recommendations are rather generic and too broad, if existing at all (see also Jacobsson & Karltorp 2012; Bélis-Bergouignan & Levy 2010). From the authors' experience working with political institutions, policy makers prefer relatively concrete and substantiated recommendations in order to find them meaningful and integrate them into existing policy.

Our paper contributes to the ongoing debate about how to improve the relevance and applicability of *TIS and functions* in research findings for the political forum. With this viewpoint we argue that by building bridges to established strands of research outside the innovation systems literature is a well suited means to better harness the potential of *TIS and functions* in terms of providing policy recommendations. This is closing a circle as the emergence of the *TIS* (Carlsson & Stankiewicz 1991) and its *functions* framework (Bergek et al. 2008; Hekkert et al. 2007) has been interdisciplinary in its outset (Johnson 2001; Fagerberg et al. 2006). In specific, we see room for making policy recommendations that are more specific and relevant by linking the functions approach, in particular the identified bottlenecks, respectively to the existing theories from related fields: We argue that economics, organizational, and/or political science are particularly well suited in this regard. Especially economic theories, which is a classical domain to formulate policy recommendations concerned with the diffusion of innovation and technologies. Organizational studies and political sciences are important to consider as they encompass central actors of the innovation system who play a very crucial role in prompting technological change. While all three disciplines promise to be relevant, the examples used in this paper mainly stem from economic theories which best reflects the authors' expertise.

Our paper is structured as follows. Section 2 summarizes the *TIS and functions* framework and its roots; section 3 introduces our *TIS and functions* fitness program. We then apply the suggested program to two selected bottlenecks in section 4. Section 5 concludes with suggestions for further development of the fitness program.

2 *A short review of TIS and functions*

The roots of *TIS and functions*

The *TIS and functions* framework belongs – together with the national, regional, and sectoral innovation system – to the literature stream of systems of innovations which broadly speaking aims at explaining technological change. Innovation systems generally assume that technical change happens through the interplay of different actors strongly influenced by their institutional environment (Carlsson & Stankiewicz 1991). The approach was developed by drawing from "different theories of innovation such as interactive learning theories and evolutionary theories" – however does not consider itself as a theory but rather a framework (Edquist 1997, p.5). The practical purpose of innovation systems is to derive policies that foster technological change (Edquist 1997).

While National Innovation System (NIS), Regional Innovation System (RIS), and Sectoral Innovation System (SIS) have a sectoral level of analysis, the TIS describes a system of innovation which focuses on one specific technology – including its development, its production and its usage. It is defined by Carlsson and Stankiewicz as a "dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology" (Carlsson & Stankiewicz 1991, p.93). In order to make the *TIS*' performance "measureable" and to derive policy recommendations on how to support a desired technology, the concept of *functions* was developed. While a *TIS* analysis describes the static elements of the system, the *functions* describe its dynamics. Thus a "deeper understanding of socio-technical dynamics provides policy makers (and other actors) with a more solid base for policy interventions"

(Geels et al. 2008). While initially introduced by Johnson (2001), Hekkert et al. (2007) it is firstly defined as a set of seven functions (see Annex 1). Bergek and colleagues (2008) provided a guideline to conduct *TIS and functions* analysis, a scheme for analysis. It describes the procedure step by step and targets at identifying key policy issues (Bergek et al. 2008). Similar to the systems of innovation, the *functions* approach has interdisciplinary roots (Johnson 2001; Jacobsson & Bergek 2004; Carlsson & Stankiewicz 1991; Malerba 2002) . The set of functions is "based on a multidisciplinary base of literature (including evolutionary economics, political science, institutional economics, sociology of technology and population ecology) and by including dynamics the TIS approach came to include a broader flora of sub-processes than if it had been limited to one discipline" (Jacobsson & Bergek 2011, p. 46).

Today, the two sets of *functions* by Bergek and Hekkert are the ones predominantly used in empirical analyses (Bergek 2012; Truffer et al. 2012),. They slightly differ in the number and definition of *functions*[1]. However, *TIS and functions* research mostly applies similar investigative questions regarding the success of a specific new technology and monitor this technology with the rigor of the proposed structure of analysis (Bergek et al. 2008; Suurs & Hekkert 2009; Praetorius et al. 2010; Hekkert & Ossebaard 2010). In the examples we provide for this viewpoint we refer to the set of *functions* provided by Hekkert et al. (2007) (Annex 1), while acknowledging the scheme of analysis provided by Bergek et al. (2008).

Advantages and shortcomings of *TIS and functions*

The framework has some clear advantages; first its uniqueness is its systemic approach that allows for integrating the different actors, networks and institutions (Carlsson & Stankiewicz 1991). Second, its interdisciplinary roots make the concept accessible to researchers from different fields (Jacobsson & Bergek 2011). Third, the combination of empirical phenomena and pragmatic theoretical choices make different *TIS* analyses comparable without ceteris paribus cases (Bergek et al. 2005; Johnson 2001; Jacobsson & Bergek 2004; Rickne & Jacobsson 1999). Fourth, TIS and functions is a handy tool to scan the innovation and diffusion process of a technology and identify bottlenecks that hinder the progression (Johnson 2001; Smits & Kuhlmann 2004; Bergek et al. 2008; Jacobsson & Bergek 2011). Fifth, its intention is to make research insights more beneficial for policy making and with this it seeks to solve real-world challenges (Hekkert et al. 2007; Bergek et al. 2008). Finally, related to all of the aforementioned points, with the capability to describe bottlenecks in their systemic nature, *TIS and functions* are therefore able to identify systemic policy issues, which is the decisive advantage of the framework (Wieczorek & Hekkert 2012; Smits & Kuhlmann 2004).

[1] Often empirical researchers build a set of functions combined of the two or slightly modified to their own best knowledge.

While the advantages are diverse, there are also shortcomings. Besides the youth of the framework and the accompanying "teething troubles" (for a list of currently debated issues see e.g., Jacobsson & Bergek 2011; Bergek 2012; Truffer et al. 2012) – a main shortcoming is that unspecific policy recommendations that are derived from these empirical studies. This viewpoint addresses exactly this limitation by proposing an approach that builds upon the *TIS and functions* framework and hence supports the framework to harness its full potential.

3 Enriching TIS & functions

Empirical research not only identifies relevant policy issues, but goes one step beyond and develops policy recommendations. A short survey of recent empirical papers applying the *functions* approach, listed in two recent reviews (Bergek 2012; Truffer et al. 2012), shows that most empirical *TIS and functions* studies focus on: (a) issues of sustainability; out of 50 papers 45 are (renewable) energy-related and (b) formulate policy recommendations to foster sustainable transitions. However, out of 50 scientific, empirical articles on TIS and functions as listed by Bergek (2012) , 45 derive very broad or no policy recommendations based on the identified bottlenecks and much less (approximately five) formulate these in a too specific, direct applicable way (Bergek 2012). Therefore, many analyses remain underexploited for informing policy in a meaningful way.

We recommend to add an additional step to the *TIS and functions*' scheme of analysis proposed by Bergek et al. (2008) where 'by analyzing weaknesses in the functional pattern of the TIS (i.e. "what is actually going on"), we can identify the key blocking mechanisms that, in turn, lead us to a specification of the relevant policy issues." (Bergek et al. 2008, p.423).

We put forth that theories that have served well in providing meaningful policy recommendations regarding very specific questions in the past could also serve *TIS and functions* scholars to solidify their policy implications. Such complementing theories encompass economic, organizational and political science theories. If one understands the *TIS and functions* framework as an indicator in order to identify bottlenecks in a system, then we propose to extend this indicator further by consulting literature that has analyzed specific bottlenecks in order to derive tailored policy recommendations to tackle these bottlenecks. With this goal, we suggest the following procedure:

1. Conduct a *TIS and functions* analysis as proposed in step 1-6 in Bergek et al. (2008): this yields a set of bottlenecks and general policy issues (each associated to specific *functions*). The six steps are the following:

    Step 1: the starting point for the analysis: defining the TIS in focus

Step 2: identifying the structural components of the TIS

Step 3: mapping the functional pattern of the TIS

Step 4: assessing the functionality of the TIS and setting process goals

Step 5: identify inducement and blocking mechanisms

Step 6: specify key policy issues

2. For each identified bottleneck (and the related policy issue), choose the literature from, e.g. political, economic or organizational science which is well suited to addresses the specific bottleneck and to develop policy recommendations.
3. Apply the theory to the bottleneck and with this help (re-)formulate a specific policy recommendation. Depending on the newness of the so gained insights it might even be fruitful to include a second iterative step and interview the most important TIS players (again) to answer questions which have newly arisen.

Identifying the complementary (economic, organizational or political) theory which fits a bottleneck best is challenging – especially for young and even highly specialized researchers. However, we are convinced it can be fruitful in order to come up with feasible policy recommendations increasing the relevance of the *TIS and functions* framework for policy-making.

As indicated above, we are utmost convinced that the most valuable theories can be found in economic, organizational and policy science. Besides political science, economic theories are the classical domain to formulate policy recommendations concerning diffusion of innovation and technologies. In addition, economic theory is one of the very few disciplines that demonstrate the ambition to provide foresighted policy recommendations daring to anticipate future conditions. However, the precise implementation guidelines for the various actors involved are not generally provided by economic theory. Organizational studies can help us to understand the inner logic of those actors in the innovation system that play a crucial role in inducing technological change (Utterback 1971; Hekkert et al. 2007; Bergek et al. 2008). Political sciences are naturally an important source for *TIS and functions* as political power or strength is prevalent in some of the functions and, if nothing else, policy recommendations are to be drawn from this analysis (Bergek et al. 2008; Jacobsson & Bergek 2011). It is a great opportunity for the TIS and functions framework to capitalize on these disciplines' findings and integrate the best and most suitable insights into their policy recommendations. This suggestion does not come out of left field, as it basically activates the very basics of the *TIS and functions* framework (Jacobsson & Perez Vico 2010).

4 Two exemplary cases

To illustrate the potential of combining TIS with other literature in order to provide more specific policy recommendations, we show ideally how additional literature could strengthen the policy recommendations within two existing papers regarding the function *market formation* (F5). The choice for this specific *function* is motivated by the natural fit of *market formation* with economic theories. Specifically, we chose empirical papers on renewable energy technologies in two different contexts, one from an industrialized country and one from a developing country. Renewable energy technology was chosen as it reflects the TIS' empirical strength along with the authors' field of expertise. The distinctive country contexts reflect that different bottlenecks and the various theories that may have to be applied in diverse geographical contexts (Binz et al. 2012).

4.1 Negro et al. (2008): Biomass gasification in the Netherlands

In the paper, "The bumpy road of biomass gasification in the Netherlands: Explaining the rise and fall of an emerging innovation system" Negro et al. (2008) apply the *TIS and functions* to identify "what really happened within the system." (p. 74f.).

With regard to the *function market formation* (F5) they identify a "lack of market formation by the Dutch government" (p. 66) in the first years of biomass gasification in the Netherlands. However, during that timeframe there was an attempt to implement biomass gasification through an initiative, which "can be regarded as the creation of a niche market for gasification technology (F5)" (p. 67). The policy recommendations based on the sum of the identified bottlenecks are given on a rather abstract level, emphasizing "a structural misalignment […] between the institutional framework within which the technology could have been developed, on the one hand, and the technical requirements on the other. Here, the government should have intervened by creating the right conditions for emerging technologies like biomass gasification, for instance by stimulating the System Functions […] The main blocking factor – throughout the entire period – is the absence of the national government with respect to a clear and consistent policy towards biomass gasification" (p. 74).[2]

Based on the identified bottlenecks which hinder the rise of an appropriate market for biogas, how could the paper profit by drawing from economic theory? We see a number of subsequent questions that economic literature could enlighten along with additional questions that policy makers would typically ask, based on our expert experience. For example, the authors proposed to create a protective environment for gasification technologies through policy/state intervention as "the innovation system did not function well enough to protect emerging technologies in the market environment" (p. 74). In

[2] More concrete policy recommendations are postponed by the authors as they understand their study as a starting point for a comparison of differently successful cases.

line with this idea, it is often agreed upon, within the economic discipline, that welfare can be enhanced by a policy targeted towards an innovative technology, in this case biomass gasification (Boadway & Bruce 1984). But *how* could and should this be done?

A key question following the authors' recommendations is the concrete choice of mechanism and its design implicating different consequences, e.g. with regard to welfare. What are potential efficiency losses due to rent seeking behavior, e.g. among project developers (Tullock 1967; Krueger 1974)? What policy (design) would indeed lead to a technology or sub-technology lock-in or lock-out (Unruh 2000; del Río & Unruh 2007; Hoppmann et al. 2013) and what are the alternatives to that chosen technology? What are potentially suitable political instruments, what are the characteristics and design option of those (Jaffe et al. 2002) and what are the different effects to be expected from their implementation (see e.g. the case of wind in (Butler & Neuhoff 2008)? To not only shed light on these questions from a theoretical point of view, a comparison with a similar case that has been evaluated ex post along these lines seems promising (e.g. PV in Germany) – as proposed by Negro et al. Such a procedure would also capitalize on one of the advantages of the *TIS and functions* approach, namely the possibility to compare cases indirectly by applying the standards of the functions approach.

4.2 Schmidt & Dabur (2013): Large-scale biogas in India

For the case of developing countries, we analyzed a paper written by Schmidt & Dabur (2013): "Explaining the diffusion of biogas in India: a new functional approach considering national borders and technology transfer". An array of bottlenecks were identified by the two authors for the *function market formation*. We focus on two bottlenecks, namely the "lack of market openness" and a "high level of bureaucracy". Both might cause a "lack of participation by private sector" combined with "favour (such as subsidies) to conventional energy and non-consideration of externalities" which negatively affects "the relative competitiveness of biomethanation technology". With regard to the national *TIS* the authors recommend to "reduce bureaucratic hurdles; [and] gradually phase-out fuel and fertilizer subsidies".

These policy recommendations directly address the bottlenecks and already mention the first important concepts in this realm. What remains unaddressed are the questions that follow from these recommendations and that would typically be asked by policy makers, e.g., how bureaucratic hurdles could be reduced? The developing economic literature and reports by practitioners from developing cooperation, such as the World Bank, proposes models to address this issue: "Removing obstacles to innovation means fighting anticompetitive and monopolistic practices, suppressing bureaucratic hurdles, and adapting the regulatory framework to support the search for and diffusion of novelty. It is a task that by nature should mobilize many areas of government—taxes, customs, procurement, and standards, for example—and requires vigilant action. This task is particularly necessary, but difficult, in developing country contexts” (IEA et al. 2010, p.13). Building on such sources, Schmidt & Dabur could have provided more concrete insights on where to start overcoming these barriers would be most efficient and more effective. Similar questions arise with regard to the policy recommendations tackling the lack of market openness, namely the removal of subsidies for fertilizers. Would it be best to gradually phase-out these subsidies, to cut them off immediately or to redistribute them (Birol et al. 1995; Stiglitz 1997). In case of the latter, what could be expected in terms of rent seeking (Sturzenegger & Tommasi 1994)? Even more far-reaching questions – that certainly would not be in the focus in a first step – would be: What effects could be expected in regard to the traditional fertilizer industry if biogas by-products replace their products? In the case of a gradual phase-out or cut-off, how would prices for agricultural products and energy prices be affected and how would an input price change in these two areas affect economic inequality and the poor (Ray 1998)? Resource reallocation, e.g. subsidy redistribution, mostly comes at a price, and what are the costs of such an expenditure-switching policy (Ray 1998)? Without answers to some of these questions, the policy impact on their analysis is likely to be very limited, giving away the opportunity for real impact in the political arena.

Having illustrated how our approach could be fruitful for two specific cases, in the following we provide a number of theories from economic and organizational sciences that potentially fit the *functions*. This list is not exhaustive, but useful to get a first impression. Often theories can differ between the industrialized and developing country context therefore we listed them accordingly.

Table 1 – Selection of other economic and organizational theories along functions of a TIS (functions as in Hekkert et al. 2007; Bergek et al. 2008)

Function	General theories	Theories specifically referring to developing countries
F1 Entrepreneurial activities	• The entrepreneur as source of creative responses and new combinations of economic value creation leading to economic change: (Schumpeter 1912; Schumpeter 1942) • Locus of entrepreneurship: (Rumelt 2005) • Entrepreneurship as a field of research: (S. Shane & Venkataraman 2000) • Geography of enterprise: (Krumme 1969) • The dichotomy of individual and opportunity as key paradigm for entrepreneurship research: (Eckhardt & S. A. Shane 2003) • Entrepreneurship research: (Acs & Audretsch 2010)	• Cultural differences in entrepreneurship: (Morris et al. 1994) • Economic development and cross-border investments: (Dunning 1958; de Mello 1999)

F2 **Knowledge development**	• Knowledge as competitive advantage: (Argote & Ingram 2000) • Strategic alliances and knowledge transfer: (Mowery et al. 1996)	• Technology transfer: (Davies 1977)
F3 **Knowledge diffusion**	• Global production networks: (Ernst & Kim 2002) • Knowledge based international growth: (Autio et al. 2000) • Absorptive capacity: (Zhara & George 2002; Cohen & Levinthal 1990; Todorova & Durisin 2007)	• International technology diffusion:(Keller et al. 2000; Keller 2001) • Industrial clusters in developing countries: (Bell & Albu 1999)
F4 **Guidance of search**	• Search cost/transaction cost: (Coase 1960; Williamson 1979; Simon 1991) • Critique of TC theory in firm context: (Ghoshal & Moran 1996) • Theory of the firm: (Rumelt 1997)	
F5 **Market formation**	• Favorability of Markets: (Smith 1776) • Markets as mechanisms to make use of disperse and incomplete knowledge in society: (Hayek 1945) • Sociological view of market creation: (Fligstein 1996; White 1981) • Networks for market development: (Coviello & Munro 1995) • Role of politics and customers in green market creation: (Wüstenhagen & Billharz 2006) • Diffusion: (Rogers 2003)	• Trade, FDI and technology transfer: (Saggi 2002)
F6 **Resource mobilization**	• Sociology's Resource mobilization perspective: (McCarthy & Zald 1977) • Opportunity perception: (Sorensen & Sorenson 2003)	• Economics of development: (Gillis et al. 1992)
F7 **Legitimacy**	• Organizational legitimacy: (Suchman 1995; Dowling & Pfeffer 1975) • Social acceptance of RET: (Wüstenhagen et al. 2007) • Window of opportunity: (Perez & Soete 1988; Tyre & Orlikowski 1994)	
F8 **Development of positive externalities**	• External effects/external economies: (Marshall 1890) • Dominant design and firm survival: (Suarez & Utterback 1995) • Competition and network externalities: (Porter 1998; Katz & Shapiro 1985)	

The theories chosen for each function are only first traces into fields that could answer the most typical questions in that field. The literature listed encompasses seminal papers in their area of expertise. They are selected to be a starting point for venues into the theories and consequently literature which would improve policy recommendations as a consequence of the bottlenecks identified in the respective function.

5 Conclusion

In this viewpoint we propose to enrich empirical analyses which are based on the *TIS and functions* framework with related theory, hence literature in order to improve the policy relevance of these analyses. In specific, we suggest to continue using the framework as a “scanner” to identify bottlenecks which hinder the innovation and diffusion of a technology. However, instead of directly deriving policy recommendations from these identified bottlenecks – as mostly being done in empirical *TIS and functions* analyses today – we propose to draw from further literature that specifically addresses each identified bottleneck and combine the findings from the *TIS and functions* analysis with these insights. This can either directly result in more specific policy recommendations or lead to questions, which – in a second iterative step – could then be addressed via interviews with actors in the TIS. In order to illustrate our arguments, we choose two exemplary publications applying the *TIS and functions* empirically and discuss how the papers’ policy recommendations regarding one specific function could become more specific by combining the authors’ findings with additional literature. Finally we offer a non-exhaustive table of literature ordered by the frameworks’ functions, which serves as stimulus for the question: which literature could help TIS scholars in making recommendations for policymakers more specific?

We are convinced of the frameworks’ large potential in terms of informing policy makers and providing them with proposals on how to support a specific technology. Policy advice is an important target of the TIS and functions framework - and empirically, most papers tackle highly relevant real world problems. However, the policy relevance of the framework remains mostly untapped – a fact that has already been recognized within the TIS community: “Due to different disciplinary backgrounds only a limited number of insights from the field of innovation studies are applied to this new and rapid growing field of sustainable socio-technical change” (Hekkert & Negro 2009, p. 584). In order to unlock the high potential of the framework and turn the TIS’ multidisciplinary into an advantage, it is necessary to make the policy recommendations more specific and enrich them with findings from other disciplines (Bélis-Bergouignan & Levy 2010).

One might ask why should TIS and functions scholar not leave the specific policy recommendations to scholars from the other disciplines (who focus on each bottleneck)? The answer lies in the frameworks’ advantage: other than most approaches the TIS and functions framework bears the potential to identify systemic bottlenecks. In many cases, only systemic policy instruments can remove such systemic bottlenecks (Smits & Kuhlmann 2004; Truffer et al. 2012; Jacobsson & Bergek 2007).

Therefore, it is important, that TIS and functions scholars provide recommendations for systemic policy intervention, which are meaningful to policy makers.

Besides increasing the level of specification, in order to escalate the policy relevance of *TIS and functions* analyses, researchers ideally make clear why policy should support the specific technology analyzed. Our literature review revealed that most papers fall short of explaining the reasons that speak for policy intervention in the first place. Specifically, if papers propose technology-specific support, the question has to be considered whether technology-specific policies are justifiable and what the (dis-)advantages of such specific instruments compared to technology-neutral instruments are (Azar & Sandén 2011). In summary, when using the functions framework to provide policy recommendations, researchers need to make an argument addressing the technology-specific normativity.

To conclude, we are hopeful, that the *TIS and functions* research will be able to increase its policy impact, when being able to provide more specific policy recommendations. At the same time, we are aware that this is not an easy task that comes at low cost. We regard this paper rather as a stepping stone in the entire discussion of how to progress transitions research.

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ANNEX 1

Definitions of *functions* by Hekkert et al. (2007, p.586f)

Function	**Definitions**
F1 ***Entrepre-neurial activities***	"The existence of entrepreneurs in innovation systems is of prime importance. Without entrepreneurs innovation would not take place and the innovation system would not even exist. The role of the entrepreneur is to turn the potential of new knowledge development, networks and markets into concrete action to generate and take advantage of business opportunities."
F2 ***Knowledge development (learning)***	"Mechanisms of learning are at the heart of any innovation process. For instance, according to Lundvall: "the most fundamental resource in the modern economy is knowledge and, accordingly, the most important process is learning" […]. Therefore, R&D and knowledge development are prerequisites within the innovation system. This function encompasses 'learning by searching' and 'learning by doing'."
F3 ***Knowledge diffusion through networks***	"According to Carlsson and Stankiewicz the essential function of networks is the exchange of information. This is important in a strict R&D setting, but especially in a heterogeneous context where R&D meets government, competitors and market. Here policy decisions (standards, long term targets) should be consistent with the latest technological insights and, at the same time, R&D agendas are likely to be affected by changing norms and values. For example if there is a strong focus by society on renewable energy it is likely that a shift in R&D portfolios occurs towards a higher share of renewable energy projects. This way, network activity can be regarded as a precondition to 'learning by interacting'. When user producer networks are concerned, it can also be regarded as 'learning by using'."
F4 ***Guidance of the search***	"The activities within the innovation system that can positively affect the visibility and clarity of specific wants among technology users fall under this system function. An example is the announcement of the policy goal to aim for a certain percentage of renewable energy in a future year. This grants a certain degree of legitimacy to the development of sustainable energy technologies and stimulates the mobilization of resources for this development. Expectations are also included, as occasionally expectations can converge on a specific topic and generate a momentum for change in a specific direction."
F5 ***Market formation***	"A new technology often has difficulties to compete with incumbent technologies, as is often the case for sustainable technologies. Therefore it is important to create protected spaces for new technologies. One possibility is the formation of temporary niche markets for specific applications of the technology […].This can be done by governments but also by other agents in the innovation system. Another possibility is to create a temporary competitive advantage by favorable tax regimes or minimal consumption quotas, activities in the sphere of public policy."
F6 ***Resource mobilization***	"Resources, both financial and human, are necessary as a basic input to all the activities within the innovation system. Specifically for biomass technologies, the abundant availability of the biomass resource itself is also an underlying factor determining the success or failure of a project."
F7 ***Creation of legitimacy***	"In order to develop well, a new technology has to become part of an incumbent regime, or has to even overthrow it. Parties with vested interests will often oppose this force of 'creative destruction'. In that case, advocacy coalitions can function as a catalyst to create legitimacy for the new technology and to counteract resistance to change."

Submission No. 235

Understanding the low carbon investment challenge – insights from transition studies

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Abstract

This paper explores how concepts and insights developed in the socio-technical transitions field can help to address the challenge of making large scale infrastructure investments which enable the transition towards a low carbon and sustainable energy system. To date the transitions literature has not paid a great degree of attention of the investment issue, tending to focus on innovation processes. While these two issues are not separate, we argue that more explicit attention need to be paid to the question of how to promote new forms of infrastructure investment which are in line with decarbonisation goals, and also existing policy priorities of affordability and energy security. The main purpose of the paper is therefore to explore how current research on socio-technical transitions can be operationalised to address this question.

1 Introduction

In order for the low carbon energy transition to be realised significant levels of investment will be required in a range of infrastructure assets which underpin the delivery of essential

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societal services such as energy and mobility. Investments in power stations, rail networks, ports, airports, pipes and wires etc. have always been an important public policy issue and historically governments have played a central role in the development of infrastructure systems because of the wider social and economic benefits that they bring. In recent decades the policy challenge in terms of investment has largely been framed in economic terms; how to create an appropriate regulatory incentive structure which facilitates the entry of private capital into infrastructure sectors, whilst also ensuring that societal goals are met. The energy transition however will present new challenges as along with the established goals of affordability and energy security, meeting renewable energy and decarbonisation targets means that institutions and policy instruments will need to change in order to bring about low carbon forms of investment (Bolton and Hawkes, forthcoming).

In this paper we ask in what ways can insights and concepts developed in the socio-technical transitions literature help to address this policy challenge? Transitions research explores how large scale technical systems such as energy, water and mobility undergo transformative change, building on a socio-technical systems perspective which analyses how interactions between actors, institutions and technologies shape spaces of reproduction (*regimes*) and transformation (*niches*) in the context of a wider socio-technical *landscape*. Although the specific issue of infrastructure investment has received relatively little attention in the transitions literature, which primarily addresses innovation issues, we argue that framing and understanding the low carbon investment challenge from this perspective can inform contemporary energy policy debates and help policy makers deal with this increasingly complex policy challenge.

The next section introduces our case, the UK power generation sector, highlighting the specifics of the investment and policy challenges faced. In section three we draw from a number of concepts and theoretical debates within the transitions literature to address our research question and in the final section we conclude.

2 Power sector decarbonisation in the UK

In this section we briefly discuss the power generation sector in the UK, outlining the policy background and how government is attempting to address the decarbonisation and investment challenge.

The figure below provides some background by showing the main generation plants currently operating in the UK and the year they came onto the system. As can be seen, the vast majority of operating coal plants were constructed in the late 1960s/early 1970s and most of the UK's nuclear investments took place during the 1970s and 80s when the system was operated by a state owned body, the Central Electricity Generating Board (CEGB). Much of the investment made by private companies following privatisation and liberalisation reforms in the 1990s has been in lower capital cost and flexible combined cycle gas turbine (CCGT) plant. It is only since the introduction of a Renewables Obligation (RO) in the early 2000s that significant levels of investment have taken place in renewable generation, primarily wind farms. The RO is a certificate trading scheme which incentives the large energy suppliers to source a certain proportion of their electricity from renewable sources. As figure two illustrates, this has begun to affect investment patterns of the six largest utilities in the sector with levels of renewable investment getting close to those of fossil fuel technologies.

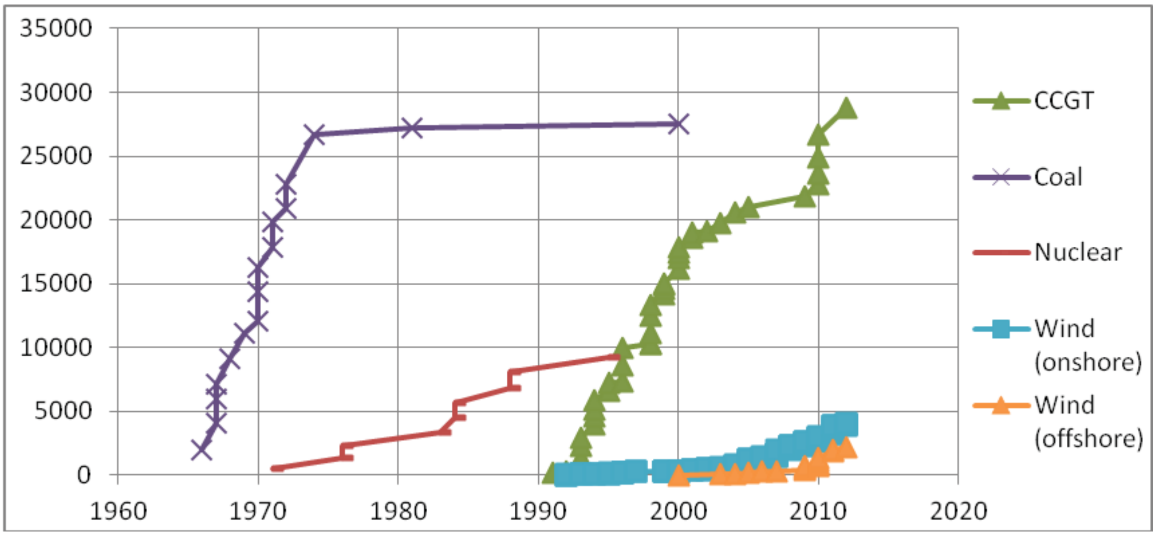

Table: Cumulative installed capacity (MW) of major power stations currently operating in the UK (DECC, 2012: data from table 5.11)

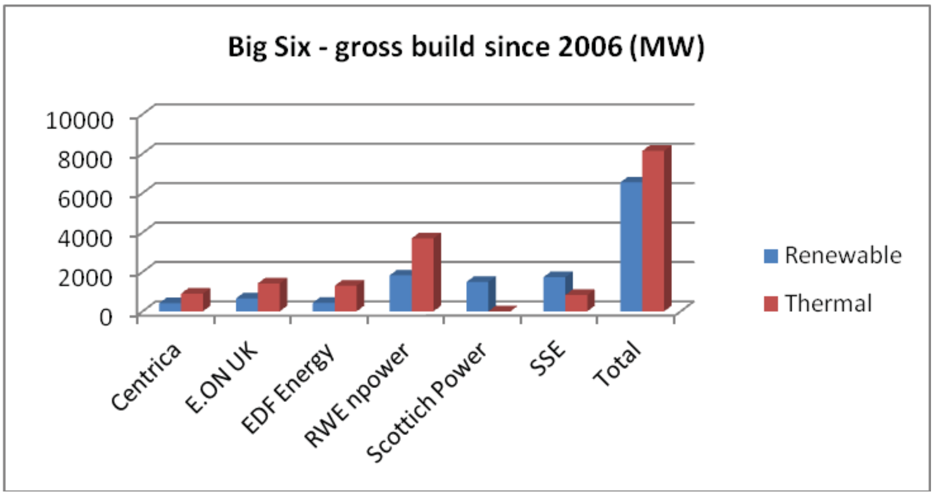

Table: Big six gross build since 2006. Data from (Bloomberg New Energy Finance, 2012)

However, despite these new investments in CCGTs and wind farms which have taken place over the past number of decades, the UK faces a potential 'generation gap' as many of the existing coal and nuclear plant will come off stream over the coming decade due to ageing plant and a lack of compliance with environmental legislation. This has lead to concerns over a short term threat to energy security due to a reduction in the level of spare capacity on the system - the capacity margin. The UK energy regulator has recently estimated that the capacity margin could fall to about 4% by 2015, from current levels of 14% (Ofgem, 2012).

Partly motivated by the fact that much of the generation fleet needs to be replaced in the coming decade, in recent years power sector decarbonisation has moved up the political agenda to become a mainstream policy objective. As part of the 2008 Climate Change Act the UK has committed to meet a legally binding greenhouse gas emissions reduction target, requiring an 80% reduction by 2050 from 1990 levels - the UK was the first country to enshrine into law such a target. As part of the 2008 Act an independent advisory body, the Committee on Climate Change (CCC), has been set up to formulate five yearly carbon budgets and to advise government on meeting its targets. In its most recent work for the fourth carbon budget (2023-2027), the CCC highlighted the importance of electricity sector decarbonisation as a central strategy in the decarbonisation of the UK economy. The motivation for this was that, relative to other energy intensive sectors, in particular heat and transport, it is likely to be cheaper and more feasible to decarbonise electricity supply first due to the availability of alternatives (i.e. renewables and nuclear). They recommended the introduction of an indicative target of an 80% reduction in emissions which will necessitate a reduction in the carbon intensity of electricity generation from its current level of approximately 500 gCO_2/kWh to 50 gCO_2/kWh by 2030. Another key policy driver for power sector decarbonisation is the UK's commitment to meet its share of EU wide targets for renewables deployment. In the UK this translates to 15% of all energy by 2020, much of which will be met from the electricity sector, with government expecting that 30% of power generation will be from renewable sources in 2020 (HM Government, 2011).

There is general consensus amongst government and industry actors in the UK that a major programme of reinvestment in the power generation sector is required to meet environmental targets and energy security objectives. The energy regulator, Ofgem, for example have estimated that during the 2010s, £110bn of investment in the electricity sector will be required, £35bn of which is for the distribution and transmission grid and £75bn for power generation (Ofgem, 2010). The consultancy Earnst and Young (Ernst and Young, 2010) estimate that £170-180bn will be required in direct capital expenditure across the power and gas sectors from 2011-2025, and if renewable heat and gas technologies are included this may total at £250bn by 2025. However, there have been many figures published with regards to the potential investment costs of the low carbon transition, indicating the fundamental uncertainty involved.

Ensuring that the necessary investment takes place in the context of the current economic and financial crisis poses an additional challenge. In their 2011 National Infrastructure Plan (HM Treasury, 2011) the UK Treasury noted that 'the principle sources of private finance for the UK's existing infrastructure pipeline – the balance sheets of utility companies and commercial banks – may face growing pressure in the medium and long term' (p.97). An industry lobby group, Transform UK[2], estimate that the traditional 'big six' energy companies have a capacity to invest £3-5bn/year whereas the requirements for a low

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2 http://www.transformuk.org/downloads/Mobilising_Investment_for_a_clean_energy_future.pdf

carbon transition is likely to be multiples of that.

In order to address the challenges of meeting targets, delivering energy security and proving certainty to investors government has put forward proposals to replace the RO as the main policy framework for investment in renewables and instead intends to introduce long term contracts for low carbon generation - nuclear, CCS and renewables. Attracting new investment into the sector and reducing the cost of financing investment - the cost of capital - have been the central motivations behind government plans.

The purpose of the paper is not to discuss these particular proposals in detail, rather to draw from our knowledge of the UK context and experience to discuss in more general terms how a socio-technical systems approach can be operationalised to address aspects of the low carbon investment challenge.

3 How can transitions thinking help us to understand the low carbon investment challenge?

In this section we discuss how the aspects of transitions thinking can inform debates on low carbon investment in the UK power sector and in low carbon infrastructure more generally. Our purpose is not to undertake a systematic review of the entire body of transitions literature (For overviews see: Markard et al., 2012, Smith et al., 2010, van den Bergh et al., 2011); rather we draw selectively from key concepts and contributions to the field which we feel have particular relevance to low carbon investment.

3.1 Challenge #1: Understanding risk and uncertainty

In thinking about long term investment in infrastructure assets such as power stations a key challenge will be to understand and manage the inherent risks and uncertainties which characterise the transition towards a low carbon energy system. Conventional approaches to evaluating investment risk and uncertainty are based on financial appraisal methodologies which rely on an identification and measurement of risks and projections of future returns over the lifespan of an investment. This presents a challenge in the context of the low carbon transition as there are fundamental structural uncertainties involved e.g.

what new forms of organisation, governance, and technological innovation will emerge over time and how will this impact on the energy system.

In the past long term scenarios have been relied upon to explore these types of structural uncertainties, however a recent methodological review of low carbon scenarios conducted by Hughes and Strachan (Hughes and Strachan, 2010) identified a number of shortcomings of traditional scenario planning methodologies; primarily an "over-reliance on constructs, notably exogenous emissions constraints and high level trends, which diminish the ability to understand how the various future scenarios could be brought about or avoided" and they proposed that a "[m]ajor improvement of low carbon scenarios of all types would be the consideration of the role of specific system actors" (p.6065).

Following Hughes and Strachan, we argue that an approach to understanding low carbon futures based on a socio-technical systems framework can contribute to a more realistic account of how the energy system might change over time, helping us to better characterise uncertainty and identify key investment risks. This would take into account a number of complex processes and mechanisms:

- Actor dynamics – the role and influence of different market, government and civil society actors and how this might change in the future (Foxon, 2013).
- Coevolutionary processes – new interactions of technologies, end user practices, business strategies, institutions and ecosystems (Foxon, 2011).
- Multi-level interactions – how spaces of reproduction (regimes) and transformation (niches) coexist and interact within a system and are influenced by a wider system context (landscape) (Geels and Schot, 2007).

A recent contribution by Foxon (2013) draws on this type of systemic approach to develop and analyse a number of low carbon pathways for the UK electricity system (Foxon, 2013, Foxon et al., 2010). Foxon (2013) considers how different actor framings of a low carbon future, or governance 'logics', might influence and shape key multi-level and coevolutionary processes in three ideal-type pathways:

- In the '*Central coordination*' pathway national government exerts a strong influence over the energy system in order to deal with the challenges of addressing energy security, rising costs and achieving emissions reduction targets. Government intervention is characterised by the setting up of a Strategic Energy Agency (SEA).

- In the '*market rules*' pathway a liberalised market framework prevails in which large energy utilities are the dominant investors. The key policy mechanism is a carbon price and private actors make their investment decisions based on this constraint.
- The '*thousand flowers*' pathway sees a more decentralised future as non-traditional investors in the energy system, such as cooperatives and local authorities, play a leading role in investing in low carbon technologies and energy efficiency programmes.

Recognising these alternative contexts within which a low carbon transition might unfold allows one to explore in a structured and coherent way potential implications for investment in different low carbon technology options. The graphs below, which are based on a quantitative assessment of the pathway narratives summarised above (For more details see: Foxon, 2013), illustrate the range of possibilities for electricity generating technologies. In the *central coordination* pathway a 'technology push' approach sees a focus on large scale centralised technologies such as nuclear, CCS and offshore wind. *Market rules* also sees a broadly centralised electricity system but with less reliance on nuclear power due to the lack of government backed long term contracts. *Thousand flowers* on the other hand sees a significant role for local and decentralised technologies such as CHP with district heating and small scale microgeneration technologies.

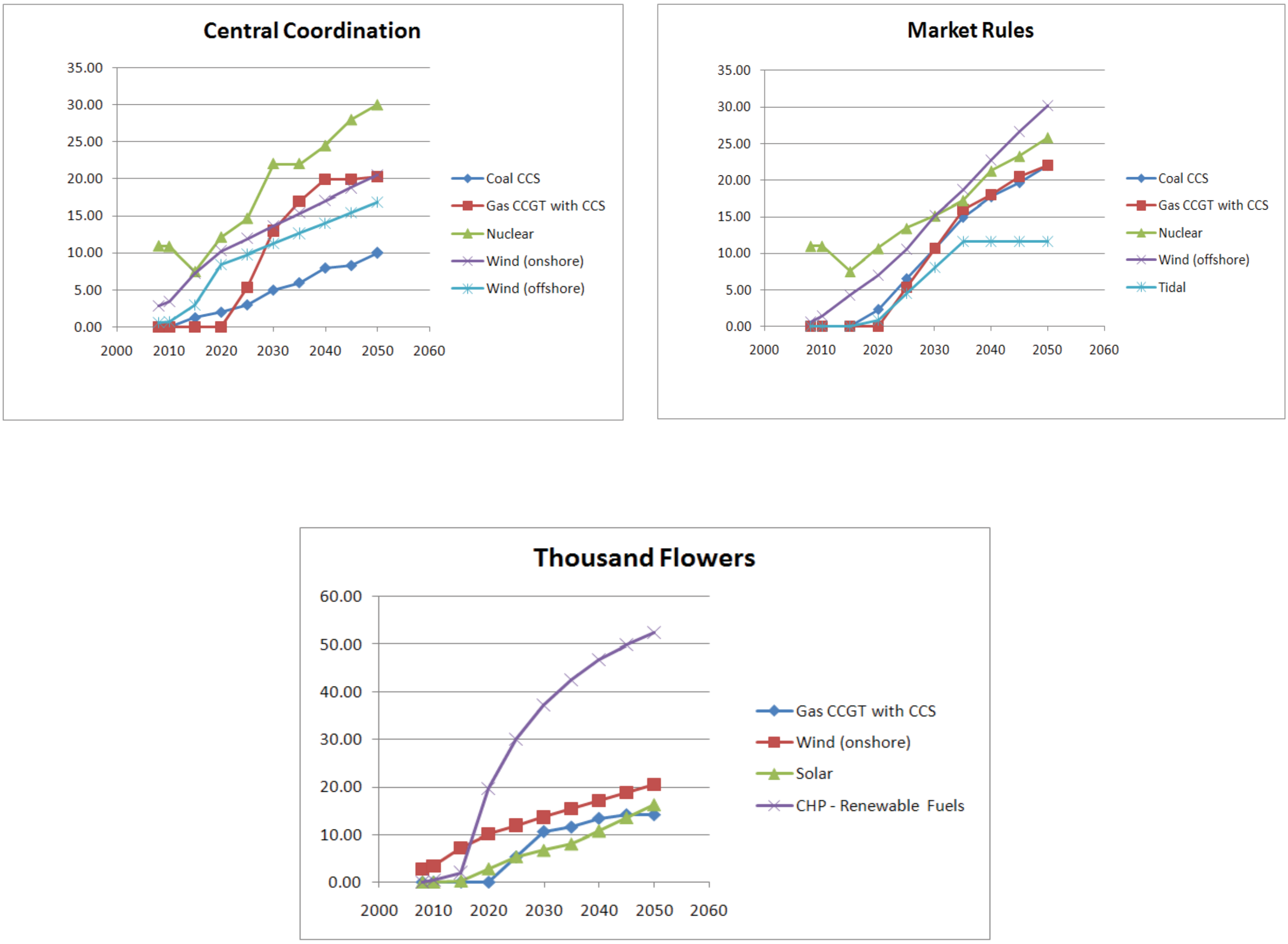

Figure: Generation investment in low carbon pathways. Source (Foxon, 2013)

This approach enables a potential investor to consider the key structural uncertainties at the heart of the low carbon future in a more realistic way and to explore the range of possible futures and outcomes in terms of the generation mix. Considering the type of pathway which unfolds would be an important first step in developing an investment strategy and a coherent technology portfolio.

Exploring these uncertainties and implications for investment risk would also be important in formulating effective policy responses at a broader governance level. A key governance challenge will be to understand how policy decisions can influence and potentially mitigate investment risk. For example in the *central coordination* pathway there is a strong reliance on nuclear technology. Recent experience with new nuclear builds in Finland and France has highlighted the high risk of cost overruns, therefore raising the construction risk in this pathway. Similarly construction risk is a concern for investors in offshore wind farms (PWC, 2010), which is an important technology in the *central coordination* and *market rules* pathways. A question for government is therefore whether specific policies are required to mitigate this construction risk e.g. by creating a bridging mechanism which spreads risk between private investors and taxpayers/customers during the early project phase.

This form of construction risk is perhaps less a feature of the more distributed *thousand flowers* pathway, however market risk may become a more significant barrier. This is because there is falling demand, many competing generators in the market and a strong reliance on government subsidies in the form of feed-in tariffs. These market risks may lead to boom-bust investment cycles and create instability in the electricity sector. Mitigating this risk could necessitate a radically redesigned electricity market structure and a stronger political commitment to renewable subsidies than has previously been displayed on the part of government.

3.2 Challenge #2: Avoiding early lock-in

The second challenge we discuss in relation to low carbon investment is the need to consider and manage the risk of early lock-in to potentially suboptimal low carbon pathways. This is of course difficult because infrastructure investments have long time horizons and in many cases investment decisions need to be made in the short term to meet immediate policy and economic goals. An important insight that can help us to think about the implications for low carbon investment is that processes of socio-technical change are non-linear and their evolution is characterised by a number of distinct phases (Rotmans et al., 2001): a *predevelopment phase* characterised by gradual change and experimentation, a *take-off phase* with more evidence of structural changes, an *acceleration phase* where these structural changes become more deeply embedded, and finally a *stabilization phase* where a new system state is reached.

How can this conceptualisation of transition phases help us to think about the low carbon transition and address the investment challenge? The energy transition in the UK is likely in the *take-off* phase as ambitious decarbonisation and renewable deployment targets have been put in place and structural changes to the electricity sector are beginning to be implemented. During this *take-off phase* the main priority is on the decarbonisation of the electricity grid, which according to the Committee on Climate Change will need occur relatively rapidly by 2030, and following this a decarbonisation of the entire energy system will need to take place, incorporating the heat and transport sectors. As was outlined in section two, rapid power grid decarbonisation is seen as a first step primarily because there are a number of low carbon options available (wind, solar, nuclear) and in any case the UK will need to replace a number of its ageing coal, nuclear and gas plants over the coming decade. The technology options for decarbonising heat and transport are not so apparent and as a result there is much less certainty as to how the post-2030 *acceleration phase* will proceed.

Creating a smooth transition from the *take-off phase* of power sector decarbonisation to the subsequent *acceleration phase* where the entire energy system becomes low carbon is therefore key. The challenge in the *take-off phase* is to develop investment strategies which help us to future proof the energy system by keeping options open as much as possible i.e. that do not close down the opportunities for niche innovations to become more widely diffused in the future. Also, in this phase the new skills, expertise, industrial capacity and supply chains which will also be required in the *acceleration phase,* will need to be developed. Transition studies points to the danger of lock-in to sub-optimal long term pathways if decisions are made solely based on narrow short term criteria, e.g. the need to plug a gap in electricity generation capacity or to meet renewable energy targets for 2020, without building the necessary foundations required for a more fundamental transformation in the medium and long term.

Perhaps there are alternative criteria which will help us to evaluate investments beyond narrow short term economic criteria. For example there may be certain strategic investments which help future proof the system and create synergies across different sectors: Taylor et al. (2012) argue that energy storage technologies fit into this category as they can help to manage a highly distributed and intermittent low carbon energy system, however under current market structures the revenue streams to investors in these technologies are highly uncertain. Identifying these strategic investments and overcoming barriers to their diffusion will likely be key to moving into the *acceleration phase*.

3.3 Challenge #3: Rethinking the role of government

In this section we discuss the role of government in ensuring that sufficient levels of low carbon investment takes place in line with environmental, social and economic policy objectives.

As was highlighted in the introduction, infrastructure investment has long been a public policy issue, there are three main reasons for this: The first is that because an efficient and reliable infrastructure system has wider economic and societal benefits, the costs and benefits of investment cannot easily be assigned to one actor group e.g. private investors. The second is that the nature of infrastructure investments differ from conventional investments because they are 'lumpy' i.e. typically large scale one off investments with extremely long pay back periods. The third reason is the systemic nature of infrastructure systems: because infrastructures such as electricity supply are complex interconnected systems there needs to be some form of overarching coordination in order to ensure reliability and efficiency (e.g. avoiding the unnecessary duplication of assets). Private investors will only have a partial perspective on the system as a whole and do not have the incentive to think beyond their own individual investment.

For these three reasons governments have historically played a prominent role in the development and expansion of these infrastructures and in many countries they remain owned and operated by state controlled bodies. In more recent decades in many European countries there has been increasing liberalisation of infrastructure markets following a programme of privatisations, with the role of the state evolving from a direct asset owner to one of market regulation. Since the 1980s there seemed to be a consensus emerging that a combination of markets and regulatory oversight would create the appropriate incentives for private actors to invest, resulting in greater efficiency and socially optimal outcomes.

However low carbon investments present a problem; due to their early stage of development they are uncompetitive against conventional technologies and investors in these technologies will face added risk as against those in conventional fossil fuel generators. This issue is problematic in the context of liberalised energy systems, such as in the UK and most other European countries, where governments have generally had a 'hands off' relationship with the energy industry, not seeking to intervene in market processes. Transitions research has questioned the degree to which markets alone can deliver substantive regime change because markets prioritise short term efficiencies and as a result innovation is confined to the parameters of the existing regime (Kern, 2009). Fundamental structural changes will be required to deliver a sustainability transition, and a new model of governance is required where market processes are no longer the central driver for innovation.

Transitions theory advocates a more interventionist role for government to create a new selection environment for low carbon technologies, and the development of a more reflexive form of governance where government, industry and civil society stakeholders negotiate in a transitions '*arena*' with the aim of creating consensus around particular visions of the future, leading to an alignment of expectations. In thinking about the specific issue of low carbon investment governments will need to decide upon an appropriate allocation of risk between energy customers, taxpayers and private investors, and investors will require reassurances that their long term investments will not be jeopardised by unexpected regulatory change or knee-jerk political decisions. Also, customers and taxpayers will require government to act on their behalf to deliver an economically, environmentally, and socially sustainable energy system for the coming decades.

3.4 Challenge #4: Attracting new sources of investment

The final challenge we discuss is the need to attract new sources of investment required to deliver the low carbon energy transition. Of course incumbent energy companies will continue to play an important role, particularly in delivering large renewable projects, CCS and nuclear as they have significant knowledge and expertise in developing large and complex infrastructure projects, typically being financed off their corporate balance sheets. However, there is a growing recognition in the UK that new sources of investment will be required because of the scale of the investment challenge and the speed of technology deployment required to meet targets. The question of how to engage with and attract institutional investors such as pension funds into the low carbon sector has become an increasingly central part of mainstream energy policy debates in the UK, and there has been much discussion surrounding the potential role that innovative financing mechanisms such as green infrastructure bonds could play in this.

While engaging with these investors will be crucial in delivering the large scale investment programmes required to decarbonise electricity grids, transitions research emphasises the need to think beyond incumbents and large scale players, directing attention towards actors currently operating outside the mainstream but who could influence change further down the line. This issue is particularly relevant to the *thousand flowers* pathway outlined in section 3.1 where the energy transition is characterised by a patchwork of local solutions, resulting in a more decentralised and distributed energy system. In this context promoting greater diversity and innovation in energy finance will be crucial to realising this transition pathway.

Relevant examples of alternative sources of energy finance include Energy Service Companies (ESCos), who unlike traditional energy companies base their business model on the provision of energy services in the most efficient way possible, and in some cases use the projected returns from efficiency savings to finance investment. A UK based ESCo, Thamesway Energy, which is wholly owned by Woking borough council, partly financed investments in CHP plants and district heating infrastructure by savings from energy efficiency measures. Private companies also operate in this space by providing energy performance contracting to customers, meaning that customers can install technologies such as domestic microgeneration at little or no upfront capital cost (Hannon, 2012). Other innovative forms energy finance operating in the UK and elsewhere include wind energy cooperatives and local currencies which have been used to bring about community scale investment.

Developments in the wider landscape will greatly influence the degree to which these alternative forms of energy investment become part of the mainstream. For example, in the UK one of the outcomes of the financial crisis has been the development and expansion of 'peer-to-peer' lending where traditional financial intermediaries e.g. banks, are bypassed.

This form of lending has been adopted in the renewable energy sector in the UK by a new venture called Abundance Generation[3] which enables individuals to invest small amounts of money directly in renewable energy projects.

A more in-depth review is required to explore the different forms of non-traditional financing to assess the extent to which they can be diffused more widely and scaled up, and the ways in which policy can encourage new forms of innovation in this area.

4 Conclusions

The purpose of this paper was to explore how transitions thinking can help us to better understand the challenge of delivering low carbon forms of infrastructure investment. Focusing on the specific case of power sector decarbonisation in the UK, we outlined four challenges facing policy makers in meeting decarbonisation targets whilst also ensuring a secure and affordable electricity supply.

In a number of important ways transitions thinking can help to address the policy challenges faced: we outlined how an understanding of alternative low carbon pathways can help us to better frame uncertainty and the associated investment risks. A more realistic and integrated socio-technical understanding of the long term future, we argue, can assist in the development of more sophisticated investment strategies and governance responses. Also important will be a more nuanced understanding of socio-technical dynamics, in particular the different phases of transition which unfold over time. We argued that in terms of the energy transition we are currently in the early part of a *take-off phase* where emphasis is on power sector decarbonisation, but that in order to enable decarbonisation of the transport and heat sectors post-2030 in the *acceleration phase*, we need to start think about putting in place the foundations for this transformation of the wider energy system now. Investment made today should therefore not be assessed soled on the basis of short term criteria such as economic efficiency or energy security concerns, but also the degree to which they are putting in place the building blocks for this later *acceleration phase*.

We also discussed the role of government and how this will need to change. Since the

[3] https://www.abundancegeneration.com/about/

advent of privatisation and liberalisation reforms, governments have generally stepped back from the direct ownership and control of infrastructure systems in order to bring about greater levels of private investment and market efficiencies. Transitions research, while not calling for a return to wholesale nationalisation and state control, argues that markets alone will not be sufficient to deliver sustainability transitions, and advocates a more interventionist role for government in directing and coordinating socio-technical change. In terms of low carbon investment, governments will need to consider the appropriate balance of investment risk between private actors, customers and taxpayers and to better articulate a credible low carbon pathway, building confidence and trust in regulatory institutions and policy processes. Finally we discussed how transitions research stresses the need to look beyond incumbent actors, to the novel forms of organisation and innovation which may currently exist in dispersed and fragmented niches. Alternative forms of energy investment do exist and have played an important role in the development of small scale renewable energy projects. We pointed to the need for a better understanding of these alternatives and the degree to which they can be scaled up and diffused more widely.

In engaging with the challenge of low carbon investment, transitions research has many insights to offer and this analysis only represents a preliminary first step. Further analysis of the overlaps between infrastructure investment and socio-technical transitions might include a more in-depth understanding of key actors in the investment community; such as investment owners (pension and insurance funds, sovereign wealth funds, high net worth individuals, retail investors), investment intermediaries (asset managers, consultants, banks), corporate utilities and project developers. There are complex interactions and relationships along this 'investment chain' which are little understood; policy makers and researchers need to develop a better understanding of how these different actors frame investment risk, their level of sector specific knowledge and expertise, and how new relationships and forms of organisation along the 'investment chain' are beginning to shape the low carbon transition. The potential to create a more synergistic and productive relationship between the energy regime and the investment community which can help to bring about a low carbon transition is surely an important avenue for future research.

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Shifting the Focus: Towards Socially Just Sustainability Transitions based on Social Innovations. An institutionalist approach

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1. Introduction

Transition theory and its policy application of transition management increasingly gains momentum both in literature and with policy makers when discussing the move towards a sustainable society. This theory has come a long way from a strict focus on technological innovations to an account which incorporates social and institutional aspects as well. However, this paper argues that this approach still has a long way to go. Indeed, transition theory has been critiqued widely in the literature (see among others Berkhout et al. 2004, Smith et al. 2005, Shove and Walker 2007, Avelino 2009, Lawhon and Murphy 2011, Eadson 2012). Here, the paper will focus merely on the following two recurring critiques. First, despite all its efforts to claim otherwise, transition theory is still technologically biased. These technologies usually lose their radical character as they are market oriented. The possibility of a radical transformation of the current society to a more sustainable one is therefore diminished. Secondly, transition theory lacks a thorough account of the power relations underpinning our society and the struggles and inequalities arising from them. As a consequence, it is an exclusionary process which does not take into account all the actors and if it does, it restricts certain actors to their role of consumers. However, to achieve a real sustainable society, transition should be socially just and inclusive. If not, struggles and inequalities will persist and will impair the move towards sustainability.

To overcome these critiques, this paper proposes to integrate an institutionalist approach into transition theory. This approach shows first of all how markets are not the only way to structure nature-society relations. The distribution of resources can be organised according to the principle of market exchange, but also according to the principle of reciprocity and redistribution. Secondly, institutionalists assign to the economy a particular place in society. They argue how institutions and social relations regulate economies and subsequently become imbued by the logic of profit. This perspective shows the contentious making of society and how power struggles arise.

This paper aims to show how transition theory could benefit from an institutionalist approach in two ways. First of all, it would shift the focus from the current market-dominated economy to alternative 'economies'. Secondly it would also shift the focus from technology innovations to social innovations. Indeed, experiments with innovative social relations are necessary to move towards alternative, more sustainable economies. By doing so, the theory could eventually move to a more just and democratic theory of sustainable transitions.

We will illustrate our argument with the case of Leuven Klimaat Neutraal 2030, a Transition Management process initiated two years ago in the city of Leuven, Belgium, with the aim of neutralising the CO_2 emissions by 2030. After two years of working, the process of Leuven Klimaat Neutraal 2030 has delivered a scientific report, which summarises the conclusions of the progress until now. This paper can only draw from the scientific report and a meeting with the thematic cell of participation. These have provided the basis for a sketchy evaluation of the visions, problem-definitions, concepts and strategies that underpin LKN2030.

This paper is structured as follows. First, it will introduce the case of Leuven Klimaat Neutraal 2030. Consequently, the transition literature which has inspired this project will be introduced. This paper focuses on the literature’s multi-level perspective and approach to Transition Management. Next, the critiques of this approach are presented and illustrated through the Leuven Klimaat Neutraal 2030 case. Fourthly, the institutionalist approach is presented and the fifth section proposes an institutionalist approach of transition theory. At this point, it should have become clear that the focus should be shifted from technological innovations to innovations in social relations. Therefore, the concept of social innovations is outlined. To conclude, an institutionalist transition theory based on social innovations is discussed and the implications for LKN2030 are outlined.

2. Transition Management in LKN2030

Leuven Klimaat Neutraal 2030 (LKN2030) is a collaborative process between the Local Authority of Leuven (which has signed the Covenant of Mayors) and the University of Leuven (KU Leuven) to make the city of Leuven climate neutral by 2030. In 2011, a one year project was set up in which partners from the local authority, businesses, civil society, the University and University Hospital worked together to prepare a scientific report, which should serve as a basis for the transition to a climate neutral city (Vandevyvere et al. 2013).

Rooted in a project-oriented approach of transition management, LKN2030 advocates both a bottom-up component and a top-down component which are centrally coordinated by a scientific coordinator and an external climate consultant (Vandevyvere et al. 2013). The whole process was guided and steered by the project management-team in which more than half of the members were representatives from the Local Authority and the KU Leuven, next to representatives from the cultural sector and Netwerk Duurzaam Leuven, a public-private partnership which promotes sustainable development projects (Netwerk Duurzaam Leuven 2013). Together with additional representatives from the City Council, the city’s autonomous urban development company (Autonoom Gemeentebedrijf Stadsontwikkeling Leuven, AGSL), the KU Leuven and representatives from key businesses, the PM team makes up the supervisory committee which "steered the process at a higher level" (see Figure 1, Jones et al. 2012, Vandevyvere et al. 2013: 16, translated from Dutch by author).

The project was split up in an operational, 'bottom up', approach of transition management and a strategic, 'top down', approach to transition management. The strategic aspect of LKN2030 entailed the setting up of a transition arena, where 20 of the most "visionary and important key actors" (Vandevyvere et al. 2013: 21, translated from Dutch by author) of Leuven, coming from the business sector, the local authority, the socio-cultural civil society[1] and the university were brought together. The transition arena, which was called 'the G20' embarked on a visioning process (Jones et al. 2012) and set out the strategic course for the future project.

For the operational aspect, 6 so-called 'thematic cells', centred around themes such as energy, buildings and the built environment, mobility, nature and agriculture, consumption and participation, were set up (Jones et al. 2012). Here, experts from the civil society, local authority, businesses and the university assembled to provide suggestions, in a bottom-up manner, to practically achieve sustainability in their field of expertise (Vandevyvere et al. 2013). The purpose of the LKN2030 'core' team was to stimulate broad support for the practical suggestions and to create a platform for a wide range of actors to have their say in the wider process towards sustainability (Vandevyvere et al. 2013)

[1] including representatives from RISO (Regional Institute for Community Development), STUK (the Arts Centre of Leuven), BBL (the independent association of more than 140 nature and environment organisations in Flanders), CAW (Center for General Welfare, which gives advice to people with problems related to health, relationships, juridical questions and the like) and 1 representative from Leuvens Klimaatforum (a series of workshop days organised by several actors from the youth organisations, non-governmental organisations and unions. Participants discuss possible steps to take in relation to some pre-defined themes).

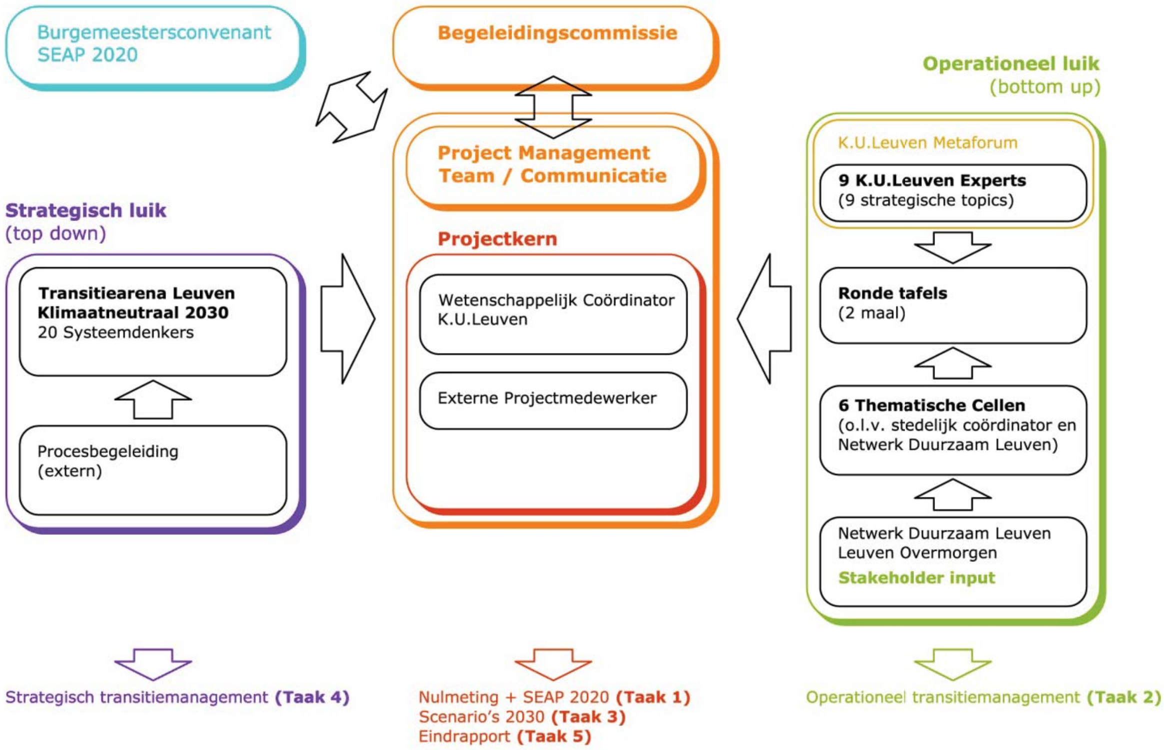

Figure 1: Project organisation of LKN2030 (Jones et al. 2012: 5)

In February 2013, the result of this one-year project, a scientific report, was presented. The report discusses the work that has been done the past year and focuses on the predominantly quantifiable measures that have to be taken within the socio-technical systems of energy, mobility, housing and nature and agriculture. Proposals are predominantly technological but also include changes in policies or individual behaviours (Vandevyvere et al. 2013). Each of the proposed measures is subjected to a cost-and-benefit calculation in order to take conclusions about its profitability, but a so-called 'X-factor' is used to provide for a qualitative account of ease of implementation (which indicates the technical feasibility of a measure and the ease in which behaviours and policies can be changed), visibility (how does the measure contribute to a positive view of LKN2030 to both external and internal actors, i.e. will actors have the feeling that "things move forward" (Vandevyvere et al. 2013: 73, translated from Dutch by author) and social responsibility (which takes into account weather the measure contributes to 'just sustainability' by evaluating if the measure accounts for all stakeholders and implements specific mechanisms of sustain or redistribution if necessary).

Furthermore, the report summarises the results of the thematic cells. Here, the deeper structural changes are described as these are necessary to achieve the so-called 'secondary benefits' of LKN2030. For Vandevyvere et al. (2013: 114, translated from Dutch by author) these secondary benefits are in particular "a higher urban quality of life and economic competitiveness".

LKN2030 is explicitly rooted in an approach of transition management. The paper now moves to explain the theories and concepts that underpin such an approach.

3. Transition theory: social actions in socio-technical systems

Based on the idea that current policy models are not suited to address complex societal problems and that sustainable development should be perceived as a continuous process rather than an end goal, the approach of Transition Management (TM) was developed. It is an open and reflexive mode of governance centred around the concept of co-evolution, which advocates that technological and social subsystems shape each other while both evolving independently (Kemp et al. 1998, Geels 2004, Kemp et al. 2007). For transition theorists, technological transitions involve not only a change from one technology to another, but also a change in the regulations, infrastructure, user practices and behaviours (Geels 2002). Socio-technical systems (e.g. energy or mobility) are the combination of elements and resources necessary for the “fulfilment of societal functions (e.g. transport, communication, nutrition)” (Geels 2004: 898). As such, the socio-technical system includes the whole set of elements and their linkages from the processes of production, distribution and consumption. These socio-technical systems are the outcome of and reproduced through the actions of social actors, who carry and reproduce the rules penetrating these systems. Social actors form different social groups[2] through the co-ordination and alignment by institutions and regimes. These social groups as well are co-ordinated and aligned to each other by a dominant set of rules, norms, structures or practices: the socio-technical regime (Geels 2004). The regime is not only reproduced by social actors; societal actions and activities for which technologies are crucial, are guided by and aligned to each other into the socio-technical regime. In turn, technologies themselves are “shot through with norms and rules, shape our perceptions, behavioural patterns and activities” (Geels 2004: 903). Following Scott (1995), Geels considers three kinds of rules which coordinate and structure activities in a coherent manner: cognitive rules (frames influencing the meaning something is given to, e.g. cultural rules or symbols give a certain meaning to objects and activities), normative rules (values, norms, rights, responsibilities) and regulative rules (formal rules, e.g. governmental rules that regulate the economy such as tax structures, property and other laws). These rules are linked together and provide the regime with stability and strength to coordinate social activities. Different groups share different rules. Therefore, there are different regimes (e.g. technological, policy, science,...). But these different rules are not completely autonomous (i.e. they do not function independently from each other as separate entities) as they are linked to each other through socio-technical regimes. For Geels (2004: 905) then, socio-technical regimes are “the ‘deep-structure’ or grammar of socio-technical systems, and are carried by social groups”. Socio-technical systems are maintained and changed by activities of

[2] For Geels (2004), social groups consist of actors who share the same problem-agendas, norms, values and are related to resources (artefacts, knowledge, capital, labour, cultural meaning) and sub-functions (production, distribution, consumption) within the ST system. Social groups related to production are for example engineers, universities or labourers. Social groups related to distribution include distribution networks and public authorities. Social groups related to consumption are users, but also media (TV, newspapers,..)

actors and simultaneously form a context for these activities. Within this context, actors act and react according to the regime and change or maintain socio-technical systems. Through this process conflicts and power struggles arise because of the unequal distribution of resources which are needed to fulfil social actions. Finally, as a consequence of these actions, reactions and changes, systems and rules are transformed. As such, the elements in socio-technical systems co-evolve.

Transition Management integrates the insights of transition theory into a long-term and reflexive management strategy and it is advocated as a whole new approach to policy and governance in that it does entail flexibility and does not include strictly measurable goals. It is inherently reflexive as the learning process is a crucial part within transition management (Rotmans et al. 2001). TM starts with a group of creative innovators, so-called ‘frontrunners’ which are brought together in a transition arena to advance a shared, long-term vision to a certain problem (Kemp et al. 2007, Rotmans et al. 2007). Visions, ideas and experiments are shaped through a collective, iterative and reflexive process wherein a continuous process of learning and evaluation is advocated. The governance methodology is advocated not as a so-called “blue-print” but as a participatory process in which the long-term vision should not only be sustained by as many actors as possible, but can also be altered based on the learning process throughout the various “transition experiments”, which are set up in the short-term to test the vision (Rotmans et al. 2001: 23). The ‘inventors’ of Transition Management do recognise that “achieving quick results with existing technology won’t do in the long term in dealing with complex social problems” (Rotmans et al. 2001: 25). They therefore advocate both improvements to the current system as well as system innovations.

As said before, transition theorists argue how ST systems are guided by a set of norms, the ST regime. Through a process of co-evolution both the regime and the system will transform. It is however difficult to transform or change a socio-technical system, once it is established. The ST system get its stability in three ways (Geels 2004): the rules, institutions and regimes provide stability by guiding the perceptions and actions of social actors. Second, these actors and organisations form networks who are interdependent from each other. Finally, the material ‘hardness’ of technologies also account for a stable socio-technical system. As such, radically new technologies are facing barriers for their development and use, such as issues related to the production, infrastructure or maintenance of the new technologies themselves or problems caused by government policies as well as cultural, psychological or demand factors (Kemp et al. 1998). Radical innovations, then, are developed in spaces protected from the mainstream market selection. Within these protected niches, experiments with radical innovations are possible and new technologies can be tested, adapted and developed further, before diffusing it into the regime (Geels 2002, Geels 2004). In short, whether or not a new technology is successful does not only depend on the technology itself but also on developments taking place in the regime. Theorists of the multi-level perspective assert that innovations break out of the niche when a certain rupture in the regime provides a window of opportunity (Geels 2002). These ruptures can be caused by several reasons (Geels 2004: 914):

1. Changes in the wider exogenous environment (landscape) might provide pressures on the regime. Climate change is an example of such a wider pressure.

2. Internal problems within a certain technology

3. Negative externalities of one system onto another. These are usually downplayed by regime actors, but here, Geels stresses the need for ‘social pressure groups’. For instance, to pursue change in ‘the regime’, consumer pressure might be needed.

4. When user preferences change, existent technologies might not be able to meet these.

5. The increase of competitiveness could also be a reason to introduce new technologies

Indeed, sometimes different regimes are mis-aligned with each other which causes activities of different social groups to go in different directions. These tensions create instability and opportunities for innovative niches to break through in mass markets (Geels 2004)

The niche formation can be managed in the sense that experiments with new technologies can be set up in a protected setting, which can be a place, area or an application (Kemp et al. 1998). The development of innovative niches can then be steered through a reflexive process called strategic niche management (Kemp et al. 1998). It involves the “creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation” (1998: 186). Within such protected spaces (niches) it is possible to test the technology, learn from its viability and evaluate its economic and social desirability, to develop it further and to change the technical, institutional and social framework in order for the technology to be diffused wider and achieve economic success (Kemp et al. 1998). While the SNM approach at first focused on internal niche dynamics, it became clear that it is not only the new technology that needs support, but the whole system of technologies and social practices linked to it needs to be changed in order to accommodate for the new technology (Kemp et al. 1998).

Rotmans et al. (2001) conceive the role of the government as supporting the current market-oriented economic system (“[governments] guarantee that a real market is created”, “liberalization and privatization are economic priorities [...]” (citations from Rotmans et al. 2001) while at the same time being involved in ‘niche management’, creating partnerships and encouraging discussions. More specifically, spaces (niches) should be created for innovative governance as an alternative to the regime (Rotmans et al. 2007). The term ‘management’ in transition management points not at a “classical command-and-control, top-down” (Rotmans et al. 2007: 11) way of managing things, but indicates the creation of space for ‘frontrunners’ and change-agents by developing a long-term vision which allows for innovative ideas by niche-players and providing financial incentives to motivate these niche-players to come up with innovative ideas and experiments. Rotmans et al. (2007) explain how transition management includes a top-down process where the agenda is being set, as well as a bottom-up process which entails the niche experiments.

The transition literature in general and the approach of transition management in particular have been subjected to many critiques. These critiques can largely be summarised into two broad themes: they are technologically biased and lack a good account of the contested nature of transitions. These critiques are discussed in the next section.

4. Critiques of transition theory

While literature on socio-technical transitions claims to address complex societal systems and advocate systems innovation next to technical innovations, “in reality[,] it focuses largely on technological change” (Eadson 2012: 104). Indeed, most research of socio-technical transitions or transition management focuses on socio-technical systems with an artefact at its core, such as transport (Hoogma et al. 2002) or waste management (Loorbach 2007). Transition theorists, Geels in particular, tries to built up a network approach with socio-technical systems, rules and actors at its core, but all this is rooted in an attempt to better understand how technical innovations can be competitive. Swyngedouw and Heynen (2003: 900)’s critique that most of the literature which focuses on “the technical aspects of urban environments fails to acknowledge the intimate relationship between the antinomies of capitalist urbanisation processes and environmental injustices” remains valid today. Indeed, while steps are taken to account for the way a technology is embedded in and produced by a society, transition theory is still largely limited to a mere description of networked arrangements. Instead, transition theory should proceed to analysing the “contested making” of these technologies and their networks (Swyngedouw and Heynen 2003: 903) and what the consequences are for social actors and their actions.

The scientific report produced by LKN2030 illustrates this technical bias. The whole report and its analysis is based on the so-called TRIAS-methodology. According to this approach, the first step to sustainability is ‘diminishing the demand’, the second step is introducing renewable resources and, finally, to account for the rest as efficient as possible. This methodology illustrates how LKN2030 focuses on technical innovations to introduce renewable and resource-efficient technologies. The first aspect of the TRIAS-methodology, however, gives an indication of how LKN2030 is consumer-oriented. Indeed, generally, socio-technical transition theorists and transition managers only account for those actors directly involved in the transition process (Lawhon and Murphy 2011). At most, ‘outsiders’ are taken into account in their role as consumers, but apart from that, they are “largely ignored in the decision-making process” (Lawhon and Murphy 2011: 361). Kenis and Mathijs (2012) have shown the difference between a behavioural change towards sustainable consumption and engaging in collective action for structural change. While the first focuses on individual choices as consumers; the latter assigns a higher role to social structures and systems and promotes collective capacity of citizens.

In contrast, Transition Management explicitly advocates a participatory approach in which “convergence and consensus is sought” (Loorbach 2007: 15). Avelino (2009) argues how such a decision making process expects certain qualities from their participants. Actors involved in transition processes should have basic competences such as: “think at a high level of abstraction [...], be able to communicate abstract ideas and have leadership abilities” (Loorbach 2007: 140). In addition, they need to be able to implement new policy designs (Avelino 2009). In LKN2030, the G20 was set up as a transition arena which set out ‘high level’ strategies (Jones et al. 2012). The G20 are explicitly chosen for their abilities and their perceived importance for the city of Leuven. The expectation of these requirements per definition excludes possible participants before the process has even started. Even though the report states that citizens should be involved in the vision-making process from the start (Vandevyvere et al. 2013: 14), it seems the project has missed the boat. While advocating a participatory approach, Transition Management actually involves an exclusionary actor-selection process. Transition Managers assume that local actors should be empowered before they are able to participate. Critical theorists have described this “imposed empowerment” (Avelino 2009: 370) as a “paradox of empowerment”(Avelino 2009: 380) as it actually enforces the dualism between the powerful and the powerless. ‘Empowered’ people become dependent from those who empower them. What’s more, it is argued that power relations cannot be changed at the interpersonal level in a ‘transition project’, but only by changing the system of power as a whole (Boje and Rosile 2001, Avelino 2009). In addition, engaging residents in a project in which the agenda and visions have already been defined and thus not inviting residents to participate in the agenda-setting, is paradoxical as well (Beaumont and Loopmans 2008). The process should therefore be more about creating a space for people to empower ‘themselves’, by “being allowed to speak their minds and openly disagree with regime-actors” (Avelino 2009: 385).

To sum up, Berkhout et al. (2004) see the concept of transition arena as a contested process. Power relations and different interests play a role in the formulation of the vision and the process of transition management excludes opinions beforehand. Finally, through the consensus-oriented approach to do “what is best for everyone”, transition goals get transformed from radical, system-wide transformations for sustainability to “technology development, global competitiveness and economic growth” (Voss et al. 2009: 289 in Paredis 2011). Indeed, the secondary benefits that will come from an increased eco-sustainability in Leuven are defined as a higher (physical) quality of life and increased economic competitiveness. This result is not surprising as it is inherent to the ambiguous role of the government, according to TM. On the one hand, government should make sure the market economy is sustained, while on the other, they should make space for radical innovations to develop. Bulkeley et al. (2013) question the possibility of reconciling the maintenance of a regime with the transformation of it. Likewise, Lawhon and Murphy (2011) have pointed to the fact that for an innovation to become mainstream, it implies a certain alignment with the regime. Thus, for innovations to be successful (i.e. to become adopted in the regime), they cannot be too radical. This can also be illustrated very well with the introduction of the X-factor in the report of LKN2030. It is a measure which incorporates the ease of implementation, the visibility and the extent of just sustainability. It follows that, the easier a measure can be implemented, the higher the X-factor. This implies that it is more aligned with the current regime and consequently, the innovation is less radical. The visibility measure implies a measure which provides the process with a 'quick-win'. When pursuing structural, long-term changes, advocated by transition theory, it is more difficult to be 'visible'.

In general, it can be argued that transition theory and its policy application of transition management refrains from questioning the power relations underpinning our society. First, only those actors are selected which are supposed to have those qualities, needed to reach consensus. Secondly, the transition approach only takes into account the actors that are directly involved with the transition process. Outsiders are only considered in their role as consumers and are forced to change their behaviour. As a result, transition goals are limited to technological innovations and economic growth and thus lose their radical character.

To address these critiques, this paper proposes the integration of an institutionalist approach into transition literature. Therefore, first, Polanyi's account of an instituted economy is introduced. Secondly, it is illustrated how transition theorists can overcome the critiques by integrating this approach.

5. Fulfilment of social actions according to Polanyi

Man depends on nature for his living (Polanyi 1982). Through the transformation of nature, material means are produced and social life is supported and sustained (Swyngedouw and Heynen 2003). Because of the continuous transformation of nature and the social relations embedded within it, not only nature but humans as well are changed and new social relations are produced and reproduced (Swyngedouw and Heynen 2003). Social actions thus always contain both physical and a social component which are inseparable from each other and intertwined into a "socio-environmental milieu" (Swyngedouw and Heynen 2003: 899, Parra and Moulaert 2011: 171). This process of interaction between the natural and social environment resulting in the supply of material means is what Polanyi (1982) defines as 'economic' and through this, social actions are fulfilled. According to Polanyi (1982) the economy is embedded and enmeshed in both economic (e.g. monetary institutions) and non-economic (e.g. religion, government) institutions and it is this *institutedness* that provides coherence to and recurrence of the different elements in the socio-environmental milieu. It provides the economic process with unity and stability according to basic structural principles through which material means are instituted (Polanyi in Jessop 2001). Throughout human history, Polanyi identifies three such principles: reciprocity, redistribution and market exchange. Reciprocity indicates mutuality between symmetrically arranged groups, for example in kinship groups. Redistribution denotes centrally-organised distribution, for example by some kind of allocative centre. Market exchange, finally, means interchanging relations through price-setting in a price-making market.

This analysis entails two things. First, it stresses that the market economy based on the principle of market exchange is not the only possible economic system. Proponents of 'orthodox' economy who narrow economic activities down to principles of market exchange, commit, according to Polanyi, an 'economistic fallacy' (Jessop 2001). Second, it assigns to the economy a distinct place within society. In non-capitalist economies, the processes of production and consumption are embedded in non-economic institutions such as the family, neighbourhood and the community (Polanyi 1944: in Jessop 2001). With the onset of capitalist economies, however, Polanyi detects what he calls a 'double movement' (Jessop 2001, Quilley 2012). First, production and consumption processes become dis-embedded from all non-economic institutions. The market economy operates autonomously for the sake of profit-maximisation. As a reaction to the "destructive anarchy of the free market" (Jessop 2001: 215) society tries to 'protect' itself by forms of regulation while at the same time allowing the system "to function according to its own laws" (Polanyi 1944: 57 in Jessop 2001). To this end, non-economic social relations and institutions (i.e. mode of regulation) need to be adapted to support and sustain capital accumulation and make sure the market economy is reproduced (Jessop 2001, Gibbs 2006). The effect of this double movement (i.e. the establishment of a mode of accumulation which is subsequently subjected to a mode of regulation) is not the re-embedding of the economy in the social relations, on the contrary, to the extent that social relations constrain and regulate the economy, social relations become embedded in the market (Jessop 2001, Quilley 2012). Self-regulation of the market is associated with the extension of capitalist relations to domains such as land and labour and through the regulation of the market mechanism, society aims at preserving man and nature (Quilley 2012). The integration of the logic of profit to domains which are not produced (e.g. land) and not for sale (e.g. labour) results in what Polanyi calls 'fictitious commodities' (Quilley 2012). The extension of the logic of market exchange to labour and land or other domains of social life, is merely one way in which market forces penetrate and dominate the society. Strictly non-commercial activities become subjected to a profit-oriented logic or a 'cost-and-benefit' calculation, accumulation is established as the dominant principle of society and other spheres of social life need to accept the principles of competition (Jessop 2001). Indeed, the market system, while autonomously making sure it gets reproduced, is structurally coupled with elements in other systems which are key for its functioning. For autopoietists argue how different systems co-evolve with each other in "complex ways with other systems with which they are reciprocally interdependent" (Jessop 2001: 217). This process of co-evolution is also influenced by social relations, values, norms and rules, in short, the society. As said above, these social relations, norms, rules and institutions have been adapted to the market economy, but the economic system autonomously makes sure it gets reproduced. “This highlights the importance of analysing how far market forces (and their profit-seeking logic) penetrate the social world and of examining the conditions for such penetration to be reproduced” (Jessop 2001: 219).

The commodification of nature and social relations, by the interference of the principle of market exchange, causes at least two problems. First, it disconnects the flows of the transformed nature (e.g. a technology) from its “inevitable foundation, [i.e.] the transformation of nature” (Gibbs 1996, Swyngedouw and Heynen 2003: 900). As a consequence, the limits to the exploitation of nature are deleted from the consciousness of society (Gibbs 1996). Secondly, however, the tendencies of the market to dominate other domains inevitably spur counter reactions and forms of resistance. As such, class or other struggles can develop. The accumulation regime, i.e. a particular set of stabilised interrelations between consumption, distribution and production, is thus full of crises and tensions, which are regulated by extra-economic social norms and practices. The economy is not only object of regulation, but also of struggle between actors and groups and through these struggles and tensions, opportunities for alternatives arise (Jessop 2001, Gibbs 2006).

6. An institutionalist approach of transition theory

Transition theory has already moved a great step forward in taking into account the structures and institutions which underpin a society. However, as shown in the previous section, an adequate account of the power relations and contentious processes which imbue the production and reproduction of current systems is often lacking. We will now move on to explain how transition theory could benefit more from an institutionalist approach. This is done in two ways. First, transition theory could benefit from a Polanyian approach as it would avoid an ‘economistic fallacy’. This would make it possible to move beyond its technological bias. Secondly, by assigning to the economy a distinct place in the society, transition theory would gain a better account of power relations and where struggles come from.

There are definitely some parallels that can be drawn between the two approaches sketched above. First of all, they both consider a system, social and material, which is necessary for the fulfilment of social actions. Indeed, transition theory asserts that social functions are fulfilled through the production and reproduction of the socio-technical system, which is actually a container concept for the processes of production, distribution and consumption. For Polanyi, the fulfilment of social actions happens through the ‘economic’ process, which entails the transformation of nature and the social relations embedded in it. The social and the physical component of social actions are therefore intertwined into a socio-environmental milieu. Secondly, both systems assert that these social activities are guided by some kind of rules that are linked together and provide stability to the transformation processes. For Geels, social groups and social actions are aligned to each other according to regulative, cognitive or normative rules and institutions or a combination of the three. The dominant set of rules is called a socio-technical regime and the linkages of the rules provides the regime with stability and strength. Polanyi argued that the economic process is embedded in economic and non-economic institutions according to one of three basic structuring principles, which provides the economy with unity and stability: reciprocity, redistribution and market exchange.

Polanyi would have accused transition theory of committing an ‘economistic fallacy’. Because of his interest in non-capitalist societies, Polanyi has shown that there is more than one economic system possible. There are systems where the economy is structured according to the principle of reciprocity or redistribution, depending on the (balance between the) societal relations it is embedded in. Transition theory, however, presumes the current economic system as a given, without questioning this. As a consequence, it has made use of a whole set of alternative theories to broaden its focus from mere technological innovations as such to the use and functionality of a technological artefact. The theory claims to account for the “social infrastructure” which is necessary to develop, commercialise and use an innovation (Geels 2004: 900). This does not only show the market-oriented approach of transition theory, its analysis is limited to the mere description of networked arrangements rather than analysing the “contested making” of these networks (Swyngedouw and Heynen 2003: 903). By acknowledging the different possible relations through which a technology could be produced, transition theory would necessarily lose its technical bias and focus on innovation in these relations instead.

‘Orthodox’ economists describe how over time, production and consumption processes have grown apart in space due to the development of more efficient transportation systems and methods of mass production (Geels 2004). This decoupling in social sciences where different approaches, who focused on either consumption or production, emerged. In his historically informed analysis, Polanyi detected the disembedding from all non-economic institutions of *both* the production and consumption processes (according to Polanyi, these are still coupled to each other and we cannot distinguish between the two) and the emerging of an autonomously operating economic system which is structured according to the anarchic principle of market exchange. Transition theorists have recognised the autopoietic (=self-reproducing) character of different systems while at the same time these systems co-evolve through interdependence. Thus, the economic system, which is predominantly concerned with its own reproduction, depends on non-economic social relations and institutions to be adapted in such a way that it allows the market system to function according to its own laws. Thus, extra-economic social relations and institutions support and sustain capital accumulation and other domains of social life become subjected to the profit-oriented logic of market exchange. Connected to this, Polanyi has detected the production of fictitious commodities, land and labour. As a consequence of the market exchange relation dominating all domains of social life, struggles of all kinds can develop and through these struggles opportunities for alternatives arise. The Multi Level Perspective of transition theory asserts that innovations arise through tensions which provide a window of opportunity for innovative technologies. These are changes in the landscape, problems related with a technology, changes of user preferences, consumer pressure due to negative externalities or increasing competitiveness. The identification of these tensions shows the market and technology oriented approach of transition theory.

Adopting an institutionalist approach, provides transition theory with a whole new framework. First of all, it would weaken the focus on the market economy as it has become clear how that is not the only possible economy. Next to this, it would also weaken the focus on technological innovations as it became clear that tensions and struggles which underpin the market economy actually arise from the extension of the dominant principle of market exchange to other domains of social life. Therefore, rather than technological innovations, transition theory could focus on innovations in social relations. By doing so, the theory could eventually move to a more just and democratic theory of sustainable transitions.

7. Satisfaction of human needs through social innovations

While it is not a new concept (see Godin 2012: for an overview), only recently, social innovation has regained momentum in scientific literature, as an alternative to the growing attention in academic literature as well as by policy-makers to technical and organisational innovations (Moulaert et al. 2005, Swyngedouw and Moulaert 2010: 220). In 'management science', it entails innovation in organisational structures, to increase the efficiency, but the term has also been used in non-profit sectors (Moulaert et al. 2005). It has been used in social economy for businesses that are reconciling commercial objectives with social ones. Some transition scholars do talk about social innovations rather than technical. These include bottom-up experiments with technologies, starting from the grassroots (Seyfang and Smith 2007, Seyfang 2009). Since here, innovations initiate from niches which have been set up outside the usual business or governmental arrangements, these are coined 'social' (Verheul and Vergragt 1995, Bulkeley et al. 2013). The 'social' in their concept of a 'social niche' seems to be denoting the non-institutional character of the actors involved, while the innovation is still technological. Hegger et al. (2007) rightly asks why there needs to be a 'detour' via technological experimentation if in the end the aim is to achieve social and institutional change.

Moulaert (2009) defines social innovation as "the satisfaction of alienated human needs through the transformation of social relations". In practice, social innovation signifies satisfaction of specific needs thanks to collective initiative, which is not synonymous with state intervention (2009: 13). For Oosterlynck and Cools (2012) it is the relations between people that need to change in such a way that socially excluded groups can address their social need. Overall, social innovation is characterised by more inclusive organisational processes which should include the excluded and by doing so, overcome exclusion (Gerometta et al. 2005). The process of social exclusion and the deprivation of social needs connected to this are at the core of social innovation. Social innovative initiatives, organised around shared visions of change, react to these processes. Through principles of co-operation, reciprocity and redistribution, equality in distribution is achieved and basic human needs are met. Through the process of defining shared visions, collective identities are created whereby change movements originate and organisations and institutions are transformed. Through this process, actors actively counter their exclusion (Moulaert et al. 2010). For including all the actors in a socially innovative process, it is necessary to develop a fully inclusive and participatory approach by providing everybody access to resources (Moulaert 2009). In short, social innovations entail three aspects: the satisfaction of basic human needs, the empowerment of deprived social groups and innovation in social relations (Moulaert et al. 2005, Moulaert et al. 2010).

Social innovation is however not only about bottom-up initiatives where basic human needs are satisfied, but about transformation in governance as well. The approach taken by Moulaert (2010: 9) stresses that next to initiatives taken at the grassroots, institutions which support and enable such initiatives through democratically-defined citizen rights and practices are necessary. Thus, social innovation entails creating *'bottom-linked'* institutions for participation and decision-making, as well as for the production and allocation of goods and services" (Garcia 2006: in Moulaert et al. 2010:12). These institutions should be embedded in broader movements and governance structures. A prerequisite for democratic governance is the empowerment of people through "jointly designed procedures of consultation and shared decision-making about the needs to be revealed and met and about the assets that could be mobilised to this end" (Moulaert 2010: 13).

These social innovations happen at the local level and, more specifically, at the neighbourhood level. Social innovation does not necessarily entail something entirely new such as a technological innovation is in technology transitions, but is about changing practices and relations who are then perceived as innovative in that specific context (Oosterlynck and Cools 2012). Indeed, social needs are context specific and the neighbourhood level functions as a niche within the broader institutional and economic spatial context where social innovative experiments can take place (González et al. 2010).

The capitalist mode of regulation is full of tensions, conflicts and inconsistencies through which spaces for experimentation with social innovations occur (González et al. 2010). These innovations challenge the mainstream order and through these experiments counter-hegemonic discourses and practices emerge. Since these practices are a reflection of the failures of the mainstream system, tensions with the state arise. The state in its turn will try to institutionalise and co-opt these initiatives (Swyngedouw and Moulaert 2010: 222). The danger, then, is that socially innovative initiatives lose their innovative character and become assimilated with the "public-managerial logic in the bureaucratic apparatuses" (Swyngedouw and Moulaert 2010: 225). In addition, socially innovative projects initiated by the state are not as successful, creative and innovative as experiments that started from within civil society (Swyngedouw and Moulaert 2010: 225). Indeed, while local policy making usually takes place at the urban scale, it is at the level of the neighbourhood where the exclusionary processes resulting from these policies are most apparent. It is the spatial concentration of socially excluded groups which triggers the highest creativity in setting up experiments for a better future (Moulaert 2010: 11).

For Parra and Moulaert (2011), ecological sustainability, economic viability and social equity are the *result* of a social innovative process involving a transformation of social power and governance relations. Although the governance for sustainability is historically and spatially specific, in any case it is about “collectively decid[ing] on, produc[ing] and encourage[ing] societal arrangements and agreements on agendas, actions and projects” which lead to sustainability (Parra and Moulaert 2011: 170). “In contrast to top-down planning and ‘environmental management’ traditions, the retrieving of social sustainability […] guarantee[s] equity and justice by means of fostering democracy and governance, which together constitute the essence of sustainable development” (Buckingham-Hatfield and Evans (eds.) 2003: in Parra and Moulaert 2011:170) .

8. Reflections on social innovation in LKN2030

This section will briefly show how a socially innovative sustainability transition could be achieved. First, the case of LKN2030 will be subjected to a short analysis based on the three pillars of social innovation. Second, some examples are given of how LKN2030 could still move towards a more socially innovative approach of sustainability transitions.

As outlined above, the three pillars of social innovation are (1) the satisfaction of local human needs, (2) the empowerment of deprived social groups and (3) innovation in social relations. First, LKN2030 did not start from these local needs. It could be argued that a more sustainable society ultimately addresses local needs, however, the point is that the problems and visions, i.e. the local need that should be met and how it should be met, have been defined beforehand by a select group of people. The problem-definition is the global climate problem and the need to address this through climate action. No explicit reference to the people and city of Leuven are made. The promoters of LKN2030 assume that there is a consensus about the need for a climate neutral city. Second, this paper has already outlined how LKN2030 did fall into the trap of the ‘empowerment paradox’. Following a strict managerial logic, the strategic aspect involved the setting out of the strategies for the city by the transition arena, G20. By explicitly looking for certain qualities in the people selected to be a member of the G20, it per definition excluded actors from the start. While advocating a participatory approach, LKN2030 warns that “the effectiveness of certain processes should always be guaranteed” (Vandevyvere et al. 2013: 39, translated from Dutch by author). This comment shows how, at the end of the day, how social and innovative as LKN2030 might present itself, it is the market logic which prevails. Finally, a member involved in the thematic cell for participation asserted how ‘innovating and challenging' LKN2030 is as it is a process which tries to bring government actors, university actors, business actors and actors from the civil society together'. Firstly, these actors are already 'empowered' and secondly, this merely resembles an enlarged public-private partnership, of which many have emerged in many cities in Europe over the recent decdes. It does not seem that LKN2030 is innovating social relations radically. Indeed, the strong focus on the profitability and economic viability of the proposed measures illustrates how: (1) the local need is not taken as a starting point. Otherwise, a cost-and-benefit calculation was not needed as there is a shift from what is needed for the market economy to what is needed for the local people. (2) LKN2030 does not empower local actors as it selects these people with specific qualities. Participation should not stand in the way of efficiency. (3) The organisational structure is a public-private partnership between the Local Authority, the University, key businesses and 'civil society'. At the moment, LKN2030 lacks inclusive organisational processes and collective initiative. The establishment of innovative relations and forms of governance is crucial to address deprived social needs.

While LKN2030 is considered a missed opportunity to some extent, the project could still actively pursue a social innovative approach. Therefore, it will need to take a step back and search for alienated local needs. It will need to analyse how people experience these local needs and how they built initiatives to meet these needs. Finally, LKN2030 should move to an approach which couples the local needs and initiatives whit each other to strengthen these initiatives.

An example of one such initiative is LETS Leuven. LETS (Local Exchange Trading Systems) is a type of complementary economy, which enables members to exchange goods and services using a local currency. LETS addresses several local material and social needs. It is an inherently inclusive process as it assumes that everyone has a talent, everybody is good at something and thus everybody has something to offer and to contribute to the LETS. In addition, there is no financial or other bench mark to participate in a LETS. Merely a participation at an information session is enough. A LETS economy entails the distribution of material means in a local network[3] organised according to the principle of reciprocity. Person A repairs the bike of person B, person B bakes a cake for person C and person C installs the printer of person A. By investing in the network, in the end this investment will return to you as a benefit. While networks of LETS are widely spread in Belgium and globally and the number of groups is still growing, its potential for sustainability transitions have not been captured by policy makers. They are however a perfect example of a radical social innovation which should be structurally sustained. The system succeeds to fulfil basic social needs, to empower local people and to change social relations. In addition, the dependency on the monetary system is reduced and the interdependency amongst community members is increased (Williams et al. 2001). Finally, by making

[3] Recently, 'inter-letsing' has been introduced as well. This entails the enlargement of the local network with another LETS network in another locality.

economic transactions more local, these are also more sustainable (e.g. reduced transportation). LETS is thus an example of a social innovation which re-embeds the economy in the social institutions.

9. Conclusion

Transition theory thus needs to account for innovations in social relations, rather than technical innovations only. We have seen that social functions are fulfilled in the socio-technical system or socio-environmental milieu. However, it seems that these systems, organised according to the principle of market exchange, are not capable of meeting the social needs of everyone. Social innovation is about the satisfaction of these alienated social needs. Through alternative structuring principles, such as reciprocity or redistribution, equality in distribution could be achieved better and basic human needs could be met. Innovating social innovations implies both a bottom-up as a top-down process. The difference with Transition Management, however, is the superiority of the bottom-up process with respect to the top-down process. What could happen here is the co-optation of social innovations by the government so that the innovations become institutionalised and lose their radical character. Indeed, social innovations are an inherently bottom-up process through which people are empowered to overcome their own exclusion, but even so it requires institutions which support and enable these innovations through collectively designed procedures of consultation and shared decision-making. Through the formation of alternative structuring principles, organisations and institutions are transformed and collective identities are created. Thus, when policy makers and other stakeholders seek strategies to move towards sustainable transitions, they should not focus entirely on new innovations and their profitability in the market economy, nor should they focus on managerial strategies on how to bring about transitions in a top-down matter.

It has been explained above how both these approaches are exclusionary and do not transform regimes in a radical way, and as a consequence not only conflicts keep emerging, but the problem of sustainability will not be solved either. Using the case study of Leuven Klimaat Neutraal 2030, which adopted a Transition Management approach, this paper has illustrated two limitations to the transition theory. First, it is technologically biased. Most research focuses on the development and commercialisation of a technological artefact. Indeed, the scientific report delivered by LKN2030 is built around a TRIAS methodology, which puts renewable and resource-efficient technologies first. Secondly, transition theory only takes to account those actors directly involved in the transition process. Outsiders are restricted to their role as consumers. In LKN2030 a transition arena, called the G20 was set up. The G20 included the ’20 most important and visionary actors of Leuven’. This illustrates the exclusionary character of the TM approach. Transition theory lacks a thorough account of the power relations underpinning our society and the struggles and inequalities arising from them. However, to achieve a real sustainable society, transition should be socially just and inclusive. If not, struggles and inequalities will persist and will significantly weaken the move towards sustainability.

Therefore, a focus on innovation in social relations is advocated and specifically innovations that started at the grassroots. By coupling transition theory with an institutionalist approach, more innovative innovations are possible and the social aspects of innovations is reinforced. These innovations should satisfy basic human needs, empower deprived social groups and innovate social relations. As a result of these social innovations, a more equitable and just sustainability is possible.

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Governance experimentation as a mechanism for influencing sustainability transitions

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Abstract:

Fundamental transitions towards more sustainable practice in different societal domains require radical change in socio-technical systems and regime structures. There is a growing body of literature highlighting the importance of strategic facilitation of formal and informal actor networks for creating such change. In particular, it is suggested that key actors who desire to enable and influence a sustainability transitions should deliberately be engaged in developing (shadow) actor networks through creation of collaborative learning environments. This requires innovation in governance compared to conventional socio-technical systems. While governance experimentation is widely seen as a starting point for socio-technical system change, there is limited insight into what a governance experiment exactly is and what it can achieve. Based on ongoing research into a real-life governance experiment in the urban water sector in Sydney Australia, this paper offers insights into the characteristics of governance experimentation and reveals that it potentially contributes to (sub) system change through development of: (i) relational capital and social structures; (ii) individual understanding; (iii) organisational priority and development; and (iv) bio-physical changes.

Keywords:

Governance experimentation; sustainability transitions; societal actors

Introduction

At present, it is increasingly recognised that traditional approaches in several domains, such as water, energy, transportation and food management, are no longer sustainable. These sectors are confronted by environmental problems, social pressures, global changes, escalating costs and various other risks and challenges (Bates et al., 2008; Pahl-Wostl et al., 2011; Palaniappan et al., 2007; Vlachos and Braga, 2001). The sustainability challenges in these domains are entrapped in their socio-technical systems through technical infrastructures and path-dependencies. The traditional technologies are interwoven with established user practices, organisational structures, and institutional arrangements (Brown and Farrelly, 2009; Unruh, 2000; Walker, 2000). These different components have co-evolved and reinforced each other and have developed into stable, established socio-technical systems (Arthur, 1989; Berkhout, 2006). While the prevailing sustainability challenges require fundamental transformations of these systems (Markard et al., 2012), they typically only allow for incremental changes to naturally occur (Frantzeskaki and Loorbach, 2010).

Fundamental transitions towards more sustainable practice in different societal domains require radical change in socio-technical systems and regime structures. Within the scholarship of sustainability transitions, the role of agency in enabling fundamental transitions is increasingly explored (Farla et al., 2012). Literature highlights the importance of strategic interplay between actors (individual and collective) in overcoming path dependence and creating support and structure for radical change (Farla et al., 2012; Musiolik and Markard, 2011). Actors pursuing and enabling a transition destabilise the regime and create opportunities for innovation through, what Lawrence and Suddaby (2006) call, ‘disrupting’ work (consisting of challenging or undermining current rules and legitimacy of institutions) and ‘creating’ work (consisting of generating new rules and structures that question and undermining existing formal and informal structures).

A recent study by Brown et al. (2013) into operational, actor dynamics over the course of a transition in stormwater management in Melbourne, contend that leading key-actors (e.g. frontrunners) are crucial for motivating and directing a transition by disrupting old and creating new institutional rules and routines. However, these leading actors are greatly dependent on their interaction with formal and informal actor networks that are aligned to the direction of the transition to actually make the disrupting and creating activities happen. The Melbourne study (Brown et al., 2013) highlights the significance of collaborative learning environments for actor network expansion and enabling actual change in the socio-technical system. This suggests that key actors who desire to enable and influence a sustainability transition should deliberately be engaged in creating and/or strengthening of (shadow) actor networks through stimulation of collaborative, learning-by-doing approaches.

Governance experimentation is a mechanism that has the potential to develop new (collective) understandings and relational capacities (Collins and Ison, 2009; Healey, 1997; Loorbach, 2010; Pahl-Wostl et al., 2008) needed to enable transformative changes in a socio-technical system. While innovation in governance is widely seen as a starting point for socio-technical system change (Elzen et al., 2004; Healey, 1997; Ison and Watson, 2007; Keen et al., 2005; Klijn and Koppenjan, 2000; Loorbach, 2010), there is limited insight into what a governance experiment exactly is. Also the extent and type of actual influence of such an approach is unknown. In particular, there is lack of empirical substantiation of outcomes of such processes (von Korff et al., 2012).

In-depth understanding of innovation in governance is critical in facilitating transitional change as it helps key-actors in their attempts to design effective strategies for influencing socio-technical system change. Recently an in-depth, empirical investigation into a real-life governance experiment held in the urban water sector in Sydney, Australia has taken place. Based on a mixed qualitative and quantitative approach, this research has not only provided insights into how governance experimentation can enable transformative change but also how such alternative forms of experimentation emerges. The research into the governance experiment has recently been completed and now there is an opportunity to reflect on how insights emerged from this empirical study furthers the fields of sustainability transitions.

The aim of this paper is, based on literature and empirical insights, to present governance experimentation as a mechanism in itself for influencing sustainability transitions. The paper, firstly, characterises governance experimentation. Secondly, it reasons why governance experimentation should be considered as an instrument in enabling sustainability transitions.

Research approach

The approach for obtaining insight into governance experimentation, involved meta-analysis of scholarly literature and an empirical case study of a successful governance experiment in the Cooks River Catchment in Sydney, Australia. Details of this study and its methods have been documented in a series of publications by Bos and Brown (2012) and Bos et al. (2013a, 2013b). This current paper consolidates the study's findings.

Overall, a single-embedded case study approach (Yin, 2009) was utilised to investigate the governance experiment and to determine its effectiveness in creating change for enabling sustainable urban water practice in the Cooks River catchment. To obtain valuable insights and cover a wide range of actor perspectives this case-study research employed a mixed qualitative and quantitative methods approach (Creswell and Plano Clark, 2007). Table 1 provides an overview of the data collection methods. The analysis and interpretation of the data involved contrasting and comparing the data through triangulation as suggested by Yin (2009).

Table 1: Data collection methods

Data Collection Method	
Interviews (Participants in governance experiment; municipal staff, project staff, consultants, community members and other catchment representatives	N= 26
Focus-group interviews (With participants within one and across multiple organisations)	N=12
Organisation - urban water management survey (Municipal staff across)	N = 86
Organisation - post experiment survey (Municipal staff across organisation that had participated in initiative)	N= 61
Community - post experiment survey (Residential community members that had participated in initiative)	N=55
Field-based observations	During visits, meetings, etc.
Documentation – Secondary data	Review of municipal strategies, policies, plans, and reports emerged from governance experiment.

Research Context

The Cooks River is a 27 kilometre long river and flows through some of the most heavily urbanised and industrialised areas in Sydney, Australia. Its catchment covers approximately 100 square kilometres and is densely populated by around 500,000 residents. It has a reputation as one of the most polluted rivers in Australia (Tovey, 2010). The institutional framework governing urban water management within the Cooks river catchment is highly fragmented. A large number of organisations, including 13 local municipalities, administer the development and management of water resources management, the provision of water services and related infrastructure, the care of public land and the natural environment. A state government owned corporation is primarily responsible for water supply, wastewater services and trunk drainage, while the Catchment Authority is responsible for catchment management and bulk water supply. Local municipalities are responsible for the stormwater drainage network.

Local urban drainage has historically not been of major importance to local government (Brown, 2005). This low priority combined with fast urban land development (as result of expansion of population), rapidly built drainage networks and poor maintenance practices, resulted in major flooding problems (Brown, 2005). Due to changing community values and global movements, environmental management and sustainability have become more important for local government over the last 20 years (Brown, 2005). As a result, the role of water in society is changing. For example, stormwater is increasingly seen as a resource, waterway amenity has become a social value, and potable water is to be conserved. In addition, a strong link between the quality of stormwater and the health of waterway has been established. Both for the water sector as a whole as for local government organisations, these new development have made water very complex as it is no longer a single engineering problem and/or dealt with within one organisation.

Between 2007 and 2011, a governance experiment took place in the Cooks River Catchment to encourage and support sustainable urban water management and practice. This experiment, named the OurRiver – Cooks River Sustainability Initiative, aimed to improve the health of the Cooks River and conserve water in the catchment. The Initiative was instigated to enhance new understandings of the urban water system among a wide range of actors (including local and state government organisations, consultants, community groups and residents) and to build capacity and collaboration for sustainable urban water practice within and between organisations, practitioners and the community. This innovation in governance was an intentional structure for deliberation and learning at local level between catchment stakeholders. Eight municipalities and a university partnered in the grant funded Initiative. Although the Initiative had an overall stated directions for improving urban water management through collaboration, there were no defined expectations of the its outcomes with regard to specific sub-catchment solutions and enhanced catchment governance arrangements. The Initiative has brought about change in the socio and bio-physical system of the catchment, which is described later in this paper. The background, emergence and organisation of the experiment have been detailed in Bos (2012) and Bos et al. (2013a).

Characterising governance experimentation

The attainment of sustainable ideologies is hampered by an incongruity between sustainability aspirations, existing technical infrastructure, institutional inertia and underpinning administrative and decision-making processes. The extent to which a sustainability ideology will be translated in practice, and have thus overcome these disparities, depends on the capacity of different societal actors to communicate, negotiate and reach collective decisions (Pahl-Wostl, 2002). Building of such ‘relational capacity’ (Healey, 1997; Pahl-Wostl et al., 2008) requires learning by which actors develop “new understanding of the kinds of role, relationship, practice and sense of purpose” necessary for managing natural resources in a more sustainable manner (Collins and Ison, 2009, p. 354). To stimulate such social learning requires change in processes and tools that shape the behaviour, decision-making and practice of societal actors (Blomquist et al., 2004; Loorbach, 2010; Pahl-Wostl et al., 2008; Tortajada, 2010; Truffer et al., 2008).

While the need for social learning through experimentation is widely recognised for overcoming system lock-in and the restructuring of societal systems (Folke et al., 2005; Geels, 2006; Loorbach, 2010; Olsson et al., 2004; Pahl-Wostl et al., 2007; Van der Brugge and Rotmans, 2007), modern society focuses much more on technical innovations than on experimentation that generates wider system learning (Farrelly and Brown, 2011; Mitchell, 2006).

It is against this background that we characterise a governance experiment as "*a formalised initiative in which multiple actors trial innovative processes and/or tools to stimulate social learning and reconfigure decision-making and action for addressing complex societal challenges*". Successful governance experimentation will have strengthened and/or established new innovation networks by which transitional change in systems and structures can be pursued and sustainability ideas can be translated into practice.

The first distinguishing feature of a governance experiment is that such an initiative is an actual innovation with novel forms of governance, outside the conventional mechanisms for addressing a certain societal issue (Hoffmann, 2011). A governance experiment implies trial and error of processes by which decision-making occurs. These processes involve, but are not limited to, interaction between societal actors who are in the traditional forms of governance unconnected or loosely related. Governance experimentation carries an implicit acknowledgement of fallibility.

The second key feature of governance experimentation is that it purposefully pursues the creation of a social learning situation in regard to a societal challenge. Therefore, such initiatives need to be guided by a learning agenda that helps actors to appreciate: i) the diversity of perspectives that exist on a societal issue; ii) the system nature of a socio-technical situation in its local, historical and cultural context; and iii) the interdependence of a variety of system actors (Collins and Ison, 2009). While broad system learning should take place among a wide range of societal actors, governance experimentation recognises that governance operates at different levels. Therefore, not all actors need to learn the same things to enable socio-technical system change (Bos and Brown, 2012) . Rather than relying on a single mechanism for social learning, governance experiments may offer multiple, concurrent processes and approaches to stimulate learning at different levels of a socio-technical system. It should be noted that individual learning (single and double loop) is encapsulated within this definition of governance experimentation.

The third important feature of a governance experiment is that while such initiatives may have a broad societal direction (normative stance), its outcomes are not pre-defined but are determined by its learning and searching processes (Bos et al., 2013b). Depending on the operational level of the innovation in governance (i.e. overall socio-technical system level or local implementation level) different outcomes are to be expected relating to change in practice, culture and/or structure. While social learning as a single outcome does not imply that a governance experiment has been unsuccessful, experience from the Sydney case study reveals that legitimacy of such a process in a technocratic, conventional socio-technical regime is gained by attaining operational outcomes such as education projects, capital works, etc.

Governance experiments differ from traditional participatory initiatives as they purposefully pursue an agenda aimed at social learning and searching for alternatives, instead of an agenda that is merely focused on participation (Bos et al., 2013a; Collins and Ison, 2009). The concept of governance experiments has similarities to transition experiments (Raven et al., 2007; Van den Bosch, 2010) in terms of focusing on a societal challenge and addressing an uncertain and complex problem through searching and learning in a multi-actor environment. However, a key difference can be found in the fact that transition experiments are "aimed at developing and learning about a specific type of innovation" (Van den Bosch, 2010, p. 232). The types of innovation in transition experiments are broad and can be a radical change in, for example, a technology, organisational culture, or regulation. Governance experiments, on the other hand, are strictly about innovations in governance for developing new perspectives and implementation of alternatives. While a new technology, for instance, may become the subject of trialling in a governance experiment, this technology will not become the primary focus and intent of the experiment.

Influencing socio-technical change through governance experimentation

Experiences from governance experimentation in the urban water sector in the Cooks River catchment in Sydney prove that there is potential for socio-technical (sub) system change. This section describes the nature and extent influences developed during such an initiative

Developing relational capital and social structures

The research revealed that actor relationships developed at three different levels within the socio-technical system of the Cooks River catchment; the sub-catchment, the municipal and the catchment level (Bos and Brown, 2012).

At the *sub-catchment level*, new relationships between actors, who were previously not related and included community members, were established to develop future visions for water in a local area. Subsequently, goals and actions to achieve these water visions were developed considering the local social, organisational and biophysical context. Options for addressing urban water management that are appropriate to the local situation are considered to be essential in developing sustainable natural resources management (Brown, 2003; Grizzetti et al., 2012). Furthermore, well developed relationships at the sub-catchment level built 'publics'. Publics, which can be seen as residential "groups surrounding common issue interests" (May, 1991, p. 190), are considered critical in increasing political commitment to collective action for sustainable practice. In this case study, creating and maintaining publics helped to secure attention and on-going support for sustainable urban water management by elected officials.

At the *municipal level*, relationships were developed between municipal actors who were previously loosely connected during the sub-catchment vision and planning activities and through the development and implementation of the subsequent actions. All organisations improved their intra-organisational collaboration as a result of the experiment. This is important for furthering sustainable practice as professional silos within organisations inhibit the development of innovative solutions in the urban water industry (Brown, 2008).

At the *catchment level*, relationships were developed across municipalities at the officer as well as at the executive levels to guide, direct and support the initiative. Actors at the officer level were loosely connected through an existing structure and there were no pre-existing formal relations between the executive actors in regard to urban water management in the catchment. The governance experiment resulted in a bottom-up change in governance structure of the Cooks River Catchment. This new institutional structure, the Cooks River Alliance, formalises the cooperative arrangement of the OurRiver-Cooks River Sustainability Initiative and is an application of the initial governance innovation. While it is beyond the scope of this research to assess its actual contribution to sustainable water practice from a bio-physical perspective, the Alliance is designed to operate as a bridging organisation that will serve as a nodal point to support and enhance sustainable practice in the catchment. Such bridging organisations reduce learning and transaction costs of collaboration, and increase social incentives for societal actors to constructively strive for achieving common sustainable solutions (Folke et al., 2005). Brown et al. (2013) considered bridging organisation instrumental in the transition in Melbourne as they "formed different types of networks and alliance over time for protecting and deepening the reach of the transition dynamics across the city" (p. 1).

Social learning, generated simultaneously at each of these three levels within the socio-technical system, was found to underpin these newly developed relational capacities (Healey 1997, Pahl-Wostl *et al.* 2008) The research also revealed that relational change stimulated, shaped and informed decision-making in ways that were unthinkable of before the OurRiver-Cooks River Sustainability Initiative started.

Developing individual understanding

As reported in Bos et al. (2013a, 2013b), it was found that changes in individual understanding occurred among a wide range of participating actors. These changes involved both single and double-loop learning.

Single-loop learning involved changes in cognitive understanding in regard to, firstly, the state and nature of managing urban water. In particular, increased recognition of the different goals pursued by various disciplines and actors involved in managing urban water was reported. Secondly, participants reported better knowledge and understanding of the functionality of systems and infrastructure, a diversity of technological options and alternative governance processes by which sustainable water practice can be achieved. Thirdly, knowledge was obtained on the effectiveness of these different processes, technologies and non-structural measures trialled as part of the experiment. In this manner, the governance experiment contributed to professional expertise, understanding and confidence in the feasibility of alternative technologies and processes.

Double loop learning was demonstrated by actors actively pursuing new forms of action beyond the initial initiative. As already inferred above, the experiment led to the desire among municipal actors to increase intra-organisational collaboration as they had gained new insights and understandings of how different professions hold diverse, complementary knowledge of importance for managing urban water. This is of significance as individuals will be increasingly required to work with other professionals in organisations to realise sustainable practices (Brown, 2005; Cettner et al., 2012).

Developing organisational priority and commitment

The results revealed that the initiative developed organisational capacity in support of sustainable urban water practice among all organisations participating in the governance experiment. In particular, the governance experiment contributed to increasing the priority and commitment to sustainable water practice in organisations that had low levels of capacity at the start of the initiative. Lack of a dedicated internal agenda and senior and/or elected official commitment to a sustainability cause is not only limiting to the development of other areas of organisational capacity but also causes reluctance for inter-governmental (May et al., 1996) or other forms of inter-organisational (Hoberecht et al., 2011) collaboration. Therefore, development of an organisation's agenda and increase in commitment as occurred in the OurRiver-Cooks River Sustainability Initiative, is required to support the potential for change in a system of organisations, which is needed for socio-technical system change as desired in the urban water sector.

Developing changes in the bio-physical system

Implementation of actions developed among societal actors at the sub-catchment level has resulted in structural measures that directly affect the bio-physical system. As a direct result of the initiative, ten site-specific water sensitive technologies that treat runoff from ≈ 5.5 hectares (≈ 31,000 kilo litres/year), and save ≈ 10,000 kilo litres /year were designed and constructed. The initiative also instigated non-structural measures to influence water sensitive behaviour such as an educational campaign.

Creating influence for change

The findings indicate that the configuration of the governance experiment was central to generating the above effects. Through a strategic arrangement of project structure and processes a dynamic was created that enables individual and collective learning. This translated in changes in the social and also the technical system of the Cooks River catchment. The experiment was designed with open project networks and a range of individuals, beyond actors who were directly concerned with on-going decision-making, were involved in the projects. Learning and practical experiences were purposefully coordinated and shared from the local to the regional level. As outlined in Bos et al. (2013a) attributes of specific importance in bringing about the above effects were: i) discovering and working together through focus projects; ii) participating in cross-municipal support groups; iii) strong leadership; iv) support from a dedicated project team; v) processes open to adjustment, and vi) availability of a realistic budget.

The study found that it is much more demanding and uncertain to successfully undertake governance experimentation than to carry out types of experimentation that conforms to existing practices and paradigms. Firstly, governance experimentation's undefined outcomes challenged existing administration procedures. Secondly, initially a high level of complexity in understanding and executing the initiative was experienced among participating actors. Thirdly, leading municipal actors revealed that the governance experiment was very time intensive. Lastly, keeping a continuous focus on the innovation in governance was challenging, especially when there problems in relation to project leadership. During this time a traditional technocratic approach surfaced, and temporarily diminished the Initiative's social and learning focus (Bos et al., 2013b).

Reflection and Conclusion

The research provides an empirical, valid case study that demonstrates that governance experimentation has the potential to foster system change in a conventional system through deliberately creating formal and informal network actor networks through stimulation of collaborative, learning-by-doing approaches. The research is addressing a critical gap in transition studies as it is widely acknowledged that there is lack of comprehensive knowledge and understanding about the (actor) dynamics and effects of transition processes through empirical investigations (Farla et al., 2012; Markard et al., 2012).

While not all participating actors fully appreciated the innovation in governance, there was widespread agreement that the initiative had created change beyond expectation and was of a nature that had not been seen before in the catchment. Therefore, governance experimentation has the potential to achieve changes in socio-technical systems that technical experimentation on its own is unlikely to realise.

From an overall perspective, a governance experiment is an innovation in governance, intended to bring about social learning that alters decision-making and actions. Therefore, with governance experimentation it is essential that sufficient investment is made in the design of processes. Such design should explicitly focus on social processes which facilitate the development of innovation networks around the societal problem in question.

The developed characterisation of governance experimentation, including its distinctive features, can be used as an analytical instrument to enhance understanding and facilitation of governance experimentation aimed at contributing to a socio-technical transition. The developed description helps to distinguish governance experimentation from other forms of innovation and/or experimentation. It highlights the importance of innovation in governance, the creation of social learning situations, and its un-defined outcomes, which informs the design and implementation of such experimentation.

The scale of a governance experiment depends not only on its purpose but also on the level of existing socio-political support for pursuing the ideology. For cases with little socio-political support, experiments can start small, like the first phase of governance experimentation in this study. However, to increase the potential influence of a small experiment on an existing regime, the actors pursuing the experimentation would need to develop strategies of how learning from such an experiment can be expanded.

If a governance experiment consists of multiple organisations, an independent, process focused leader should be considered for facilitating of the overall governance experiment. An external leader is likely to be seen as more objective and perceived not to be favouring any of the participating actor(s) (organisations). If a dedicated project team is appointed, expectations related to resource intensiveness need to be shared at an early stage in order to keep momentum and prevent conflict or disappointment. However, it should be understood (or made to be understood) among all participating actors that the outcome of such an experiment is not pre-defined and that therefore flexibility is needed. This is a radical concept and requires regular reinforcement and re-commitment through the experiment.

Enabling a sustainability transition, whether in the domain of urban water management or elsewhere, requires the policy makers to consider governance experimentation alongside technical experimentation in reform programs. This paper demonstrates to all actors with an interest in sustainability that transition-oriented governance approaches have the ability to create change in conventional socio-technical systems.

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Regime dynamics in the Dutch energy transition

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Abstract

The Dutch energy system is changing. But what exactly is changing, what the drivers for change are, in what direction the change is, or should be heading and at what speed is disputed. Which interpretation prevails is the outcome of a discursive struggle in which the regime has most power to get its interpretation of events across to decision makers and the public. In transition literature the regime is often conceptualized as a uniform structure that generally resists change. In this research we approach the regime as a dynamic constellation of diverse actors that generally reproduce shared culture, structure and practices, but can have diverging interpretations of events and developments. Based on a case-study of the Dutch energy transition, we show that uncovering these diverging interpretations is key to understanding regime dynamics in an on-going transition challenge.

Keywords: regime, destabilisation, energy transition, discourses, the Netherlands, agency.

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1. Introduction

Curbing the impacts of the energy sector is a topic that is high on the political agenda in European countries especially after the alarming debate around energy security and its implications for a healthy and safe environment in the wake of the Fukushima nuclear disaster. The European Parliament and Council have agreed on targets to increase the share of renewable energy in the total energy supply in 2020 to 20%, to increase energy efficiency and reduce emissions of greenhouse gases with 20% compared to 1990 levels, the so-called 20-20-20 targets (EC, 2009; Klessmann, et al 2011). Also a *Roadmap 2050* and a *Power Perspective 2030* have been developed to explore possible energy futures for the European Union (EC, 2011; ECF, 2011). This has led the European Commissioner for Energy Günther Oettinger to state that the EU is going through an energy transition (EC, 2012).

What such an energy transition entails is understood differently amongst actors in the energy sector in every country. It is often the case that the discourse about energy transition is tautological to the storylines about tackling climate change by reducing CO_2 emissions (e.g., ECF, 2012), or to storylines about the need to take action about security, environmental pollution, excessive water use and resources' dependency (Scheer, 1999; Ecofys, 2011). This plethora of interpretations of an energy transition shows that the complexity of the transformative process in both supply and demand of energy inflicts and is the subject of a discursive struggle (Hajer, 1995).

From a transitions perspective, it is the regime, defined as 'systems of dominant culture, structure and practices that are shared by groups of actors' (Grin et al., 2010:131-132) that has most power to interpret events that can divert its course of action like the Fukushima nuclear disaster for the energy sectors in Europe (Huenteler, et al 2012; Thomas, 2012). It is made up of actors across energy companies, ministries, research institutes, civil society and citizens that share and reproduce the culture, structure and practices. In the transitions literature the regime has often been conceptualized as resisting change. Therefore, in order for fundamental change to take place, regimes need to destabilize or open up (Verbong & Loorbach, 2012). The regime is often conceptualized as a homogeneous and static entity that generally resists change (Geels, 2002; van der Brugge, 2009). Recent work investigating the role of regimes in changing the European electricity and natural gas sectors by Vleuten and Högselius (2012) however, shows that regimes have also been a source of change but they favour incremental change that conserves their structure in terms of form and power. Thus far the scholarship on regime processes concludes that regimes object to change and if they show increments of change these are for their own preservation rather than favouring transitions or uptaking of sustainability innovations. With this in mind, a more refined understanding and thus investigation of the regime dynamics is needed or as argued: 'operationalization of the regime concept in the context of the analysis of on going transitions calls for developing a more refined understanding of regime structures and regime actors, as well as of their interaction with emerging niches' (Loorbach & Verbong, 2012:320-321). In this research we conceptualise the regime as a dynamic constellation of diverse actors that reproduce shared culture, structure and practices, while having diverging interpretations of events and developments. Uncovering these diverging interpretations is key to understanding regime dynamics in face of a challenge or crisis. Furthermore, by looking into what the energy transition means for different actors involved in an energy system and not taking its meaning for granted, the debate could be taken a step further into unravelling motives, interests and expectations that are the drivers behind actions or inactions. Finally, it could help to identify opportunities to push the energy system in a more sustainable direction.

The research focuses on the Dutch energy system and aims to explain the current on-going phase of regime destabilisation that follows the well-researched lock-in of the past (Kemp, 2010; Loorbach, Brugge, & Taanman, 2008; Loorbach, 2007; Verbong & Geels, 2007). Regarding the adoption and diffusion of renewable sources of the energy supply sector, the Netherlands is lagging behind compared to other European countries with an increase in the share of renewable energy in final energy consumption from 2.6% in 2006 to 3.8% in 2010, when the average of EU-27 has increased from 9.0% to 12.4% (Eurostat, 2012).

The article is structured as follows: In section two the theoretical framework underlying our dynamic understanding of the regime and the methodology for studying diverging interpretations of regime actors will be introduced. Section three encompasses the results, first a dominant storyline that is shared by most regime actors is presented and then tensions within and challenges to this dominant storyline are pointed out. In section four the results and their implications for studying societal change processes are discussed. Section five contains the conclusions, an outlook regarding the future of the Dutch energy transition and we will provide recommendations for further research.

2. Theory and methodology

The main focus of this research is on the Dutch energy regime. Within transition studies the regime is understood in different ways. Geels and Schot (2010) build on the notion of technological regimes - cognitive routines that direct R&D activities in certain directions (Nelson & Winter, 1982 in: Geels and Schot, 2010) - with insights from neo-institutional theory to conceptualize socio-technical regimes. These contain cognitive, regulative and normative rules. The rules of a socio-technical regime provide stability to a system and can result in technological lock-in. Smith & Raven (2012) view the regime as a multidimensional selection environment. Holtz et al (2007) identify five defining characteristics of regimes: ‘[they] serve a purpose, are coherent, are dynamically stable, they are not guided by a single actor or small group of actors and they are autonomous’. This characterisation helps in demarcating the regime, but provides little help in understanding regime change. Rotmans and Loorbach (2010) approach transitions as taking place in complex adaptive systems. They put less emphasis on technology as a driver for societal change than Geels and Schot (2010). Rather transitions imply a shift in dominant actors, institutions and practices. They therefore define a regime as ‘systems of dominant culture, structure and practices that are shared by groups of actors' (Grin et al., 2010:131-132). Culture encompasses shared visions, values and paradigms. Structure involves institutions, economic order and physical infrastructure. Practices are daily routines, rules and behaviour of people within the system. The culture, structure and practices mutually constitute and reinforce each other, thereby providing stability to the system and resistance to change.

From a transitions perspective, the energy system is viewed as a complex adaptive societal system. Such systems are in open exchange with their environment and build on an incumbent structure that is optimized to adapt to external changes as well as to internal innovation. It is interconnected with other societal systems such as food production, mobility and construction and embedded within society. Taking into account these considerations the energy system can be defined as 'all actors and artefacts that together produce the societal function energy' (Verbong and Loorbach, 2012:9).

The regime includes for example the vested interests, consumer habits and regulation that generally work towards upholding the status quo (Grin et al, 2010; Vleuten & Högselius, 2012). In the energy domain, the status quo is characterized by a centralized and top-down organized production and distribution system which is predominantly based on fossil-fuels and high levels of energy consumption (Loorbach and Verbong, 2012).

In order for transitions to take place it is argued that regimes need to destabilize or open up under pressure of the niche- and landscape level (Grin et al., 2010; Loorbach & Verbong, 2012). As Rotmans and Loorbach (2010:132) put it:

> 'transformative change to regimes can occur through two different mechanisms. On the one hand, pressure from the social surroundings can lead to the discussion of regime structure, culture and practices, while on the other, learning processes concerning alternative options and the forming of new actor networks in niches can produce bottom-up pressures to regimes. Such pressures are taken up by the regime-actors who may take a defensive approach (by discrediting the other actors), a reactive, accommodating approach (of system improvement) or an innovative approach by contributing actively to a transition. They may also do all three things in the course of time. Regimes thus play a crucial, decisive role in transitions.'

How such regime dynamics play out in contemporary transition challenges is however not well understood, because the regime is conceptualized as a homogeneous and static entity that generally resists change. In order to understand regime dynamics different scholars argue for more refined understandings of the regime. Van der Brugge (2009) distinguishes actors, structures and processes within the regime, while Vleuten & Hogselius argue for more symmetrical regime analysis that also looks into the way regimes promote societal change. Meadowcroft (2009) opens the door to a more radical possibility that 'when we talk of 'energy' […] we are dealing not with single 'regimes', but with a complex array of partially overlapping and nested systems.'

In this research we argue that the basis for a more refined understanding of regime dynamics is found in the starting point of transitions, the persistent problems modern societies are confronted with and to which transitions form a response. The persistent problems that drive a transition are seen as symptoms of unsustainable societies and are similar to what Rittel and Webber (1973) call 'wicked problems' (Loorbach & Verbong, 2012). The main characteristic of such problems is that their very nature and conceptualization are not well understood. Loorbach (2007:14) argues:

> 'the diversity of perspectives on what a persistent problem is and what solution is preferred, can be understood when one takes into account that single actors only see parts of the whole society. Their perspective depends on their own history, roles, interests, knowledge, activities and so on but also on their specific place in a system, the level of scale they operate at and the time-horizon they work upon.'

Complex systems theory in which the transition literature is rooted argues that it is possible to have more than one description of a complex system:

> 'since different descriptions of a complex system decompose the system in different ways, the knowledge gained by any description is always relative to the perspective from which the description was made. This does not imply that any description is as good as any other. It is merely the result of the fact that only a limited number of characteristics of the system can be taken into account by any specific description.' (Cilliers, 2005:258)

This observation is especially relevant in social change processes, as during change the 'conflicting certainties' (Schwarz & Thompson, 1990) of actors emerge - often implicitly - through clashes in problem definition and consecutive goals. It means that if and how pressures are picked up and interpreted will differ between various (regime) actors (Cilliers, 2005; Schwarz & Thompson, 1990; Zuckert, 1991). Accepting the possibility of differing understandings of transition dynamics is the key to understanding regime dynamics in societal change processes. Rotmans & Loorbach (2010) argue that pressures to the regime can either come from the landscape or from the niche-level. They argue that 'such pressures are taken up by the regime-actors who may take a defensive approach (by discrediting the other actors), a reactive, accommodating approach (of system improvement) or an innovative approach by contributing actively to a transition.' However, before an event or activity is recognized as a pressure, it first requires interpretation, and actors' interpretations of 'pressures' will differ across the regime.

2.1 Methodology

This research aims to unravel actors' (possibly differing) interpretations of the challenges facing the Dutch energy regime. In order to do so, it draws on insights from discourse analysis. Argumentative discourse analysis (ADA) deals with systematically unravelling perspectives or frames, which are defined as processes of meaning and interpretation that underlie what people do and decide (Hajer, 1995). At the centre of analysis are storylines with which actors give meaning to the world they experience and the assumptions that inform the storylines. Storylines are defined as 'a generative sort of narrative that allows actors to draw upon various discursive categories to give meaning to specific physical or social phenomena. The key function of storylines is that they suggest unity in the bewildering variety of separate discursive component parts of a problem' (Hajer, 1995:56). Because argumentative discourse analysis was developed (partly) based on the Dutch context and dealing with thematic of sustainable development, it is well suited to investigate the Dutch energy domain in its pursuit of a more sustainable future (Smith & Kern, 2007).

Argumentative discourse analysis prescribes an initial scan of the field as a first research step to get a feel for what is going on in the domain under study (Hajer, 1995). Therefore a scan of the Dutch energy system, including desk research and several (telephone) interviews with actors in the field, has been carried out. The respondents were intermediaries active in the energy field because these professionals have a broad overview of the field. By asking which actors they regarded as 'powerful' in the Dutch energy domain, it was possible to draft a crude overview of the Dutch energy regime. The Dutch energy regime is formed through a complex interplay between people working for energy companies, ministries, NGOs, research institutes, intermediaries and energy consumers. The ministries of Finance and Economic Affairs, Agriculture and Innovation play an important role as they collect and distribute natural gas and tax revenues which sum up to about €35 billion a year (Algemene Energieraad, 2012). According to the intermediaries that were interviewed at the start of this research, also the Ministry of Infrastructure and the Environment and the Ministry of the Interior play a role, as they are responsible for climate policy and the built environment respectively. Also energy businesses such as Royal Dutch Shell, GasUnie, GasTerra, the large utilities Essent, NUON, Eneco and grid operators such as TenneT, Alliander and Stedin have an important stake. Furthermore, knowledge institutes such as the Dutch Energy Research Centre (ECN), the Clingendael International Energy Programme (CIEP) and TU Delft were mentioned. Also interest groups were assigned a prominent role, the most important ones being: On the one hand users of energy represented amongst others by the association for large consumers of energy and water, VEMW. On the other hand there is the energy sector which is often represented by Energie-Nederland. According to the respondent of Energie-Nederland his organisation is '*the* association for *the* [Dutch] energy sector'. Both users and producers of energy are represented by the confederation of Netherlands industry and employers, VNO-NCW, to which the president of Energie-Nederland is also a board member. Finally, also environmental NGOs have a role, most prominently Stichting Natuur & Milieu.

After this initial scan of the field, interviews have been conducted with fourteen respondents. Including representatives of Energie-Nederland the association for the energy sector; with several of its members, of which the majority from large utilities, but also with a respondent from GreenChoice, a relatively new and small player that provides only green energy. Then also respondents from organisations in the direct environment of the association were interviewed, namely from the Ministry of Infrastructure and the Environment (I&M), the Ministry of Economic Affairs, Agriculture and Innovation (EL&I), the Confederation of Netherlands Industry and Employers, VNO-NCW, the association for large consumers of energy and water, VEMW and ECN, the Dutch energy research centre. Respondents from these organisations work at the interface of energy policy and industry and therefore were assumed to be able to provide valuable insights in the challenges facing the energy sector.

Respondents were interviewed on personal title and anonymity was granted in reporting the results. However, in order to come to meaningful conclusions, we will refer to the organisational context in which a respondent operates. Still it should be stressed that the views provided are those of the respondents and not necessarily that of the organization they work for. This was communicated with respondents prior to the interview. The interview was conducted in a semi-structured manner (Baarda et al., 2000), thereby leaving room to zoom in on specific aspects raised by respondents. The interview was used to get an understanding of the image respondents have of the energy domain, its future and their positioning in it and how they relate to other actors within the energy domain. Also, (follow-up) questions were asked to get an insight in the underlying assumptions respondents have of certain developments in the energy domain and the drivers behind change in their sector. The interviews were recorded and the recordings were fully transcribed. With the help of MAXQDA qualitative data analysis software the transcripts have been coded and prepared for analysis. The coding happened in two steps: open coding followed by axial coding (Boeije, 2009).

In step four, the findings of step three are interpreted by first reconstructing the dominant storyline that currently guides the energy sector. Afterwards this storyline was reflected upon and tensions within the dominant storyline and discursive elements that pose challenges to this storyline have been identified. Such elements were recognized by looking for signals of confusion, insecurity, conflict and marginalization or exclusion of other storylines through and-and and or-or constructions. The aim has been to present quotes from the interviews as complete as possible, to make sure that the context of the quote is clear for readers. A point of concern here is that the original data were in Dutch and needed to be translated into English. To make sure the used quotes and their translation aptly capture the intentions respondents had, the final concept version has been checked with respondents and minor changes have been made based on respondents' reactions to clarify the meaning of certain quotes.

3. Results

The dominant storyline that emerged from the interviews regarding the future of the Dutch energy system is 'decarbonisation in a European market, while keeping the energy supply secure and affordable' see Box 1. Most comments from respondents related to this storyline and the challenges the mentioned regarding the future of the energy domain are tackling climate change, however this is only one of the three pillars of energy policy. Keeping the energy supply secure and affordable in future is equally important as making it more sustainability. We will elaborate on the substorylines underlying the dominant storyline.

Box 1: Dominant storyline and its underlying substorylines

Dominant storyline:
decarbonization in a European market, while keeping the energy supply secure and affordable.

Substorylines:

I. climate change is main driver and decarbonization therefore the main goal
II. sustainability is only one of three pillars of energy policy
III. the market is the preferred ordering principle for the energy domain
IV. energy sector should be organized at EU-level
V. ETS should be leading in reducing CO_2

Substoryline I: "climate change is main driver and decarbonisation therefore the main goal"

Reducing CO_2-emissions is seen as the main challenge for the energy sector by most respondents, although the respondent from VNO-NCW puts more emphasis on improving energy and resource efficiency as a key competitive concern: 'resources and energy become scarcer and more expensive, which makes it interesting to develop more efficient techniques.'

Societal and political concern about climate change is seen as the main driver behind the energy transition. Often specific reduction goals were mentioned for the year 2050, e.g., the respondent of Delta states that his company 'has the ambition to be CO_2-neutral by 2050'. In the view of Delta, nuclear power can be part of that mix as well. The respondent of Energie-Nederland formulates it as follows:

> 'In 2050 we want to realize a CO_2-neutral energy supply with as much renewable energy as possible. However, because we estimate that it will not be possible to run on 100% renewable

energy in 2050, we should also think about how to involve fossil energy in a CO_2-neutral way. That means applying CCS[4] to coal and gas fired power plants.'

The substoryline of this section could be summarized as: 'climate change is the main reason for changing the energy system, therefore the focus should be on CO_2-reduction.'

Substoryline II: "Sustainable, Secure and Affordable"

The decarbonisation goal as discussed in the previous paragraph is often displayed as conflicting with the other pillars of the 'golden triangle' of security, affordability and sustainability of the energy supply. As the respondent of Essent states:

> 'the tendency to prioritize renewable energy comes at the expense of security and affordability. […] We should catch up on the renewables goal, but in a way that does not cannibalize the other two.'

Also other respondents state that keeping the energy supply secure and affordable is important and that making the energy supply more sustainable should not go at the expense of the other two. The respondent from VEMW states for example: 'Often the issue is looked at from only one side, like sustainability is something that can be isolated from the energy discussion. You asked me what the challenges are, well there are three.'

The substoryline discussed in this section could be summarized as: 'sustainability is only one of three pillars of energy policy and therefore equal attention should be paid to keeping the energy supply secure and affordable.'

Substoryline III*: "* *the market is the preferred ordering principle for the energy domain"*

The market is the preferred ordering principle for the energy sector according to most respondents and should therefore be leading in achieving the decarbonisation goals. And as the energy sector is increasingly becoming a European sector, the European level is the preferred scale to set these conditions. As the respondent from VEMW formulates it:

> 'we focus strongly on the market, after all we all agreed in Europe to organize our energy supply through the market. We think that that is a good idea, because in a market everyone can play a role in providing solutions for this enormous problem.'

Essent's respondent goes a step further: 'markets provide information about the future. When you can sell your electricity ten years ahead, you can basically look into the future.' The respondent from VNO-NCW explains that market forces will organize sustainability: 'businesses see that resources and energy become scarce and therefore markets are developing in those areas internationally. There are

[4] Carbon capture and storage

actually two things, customers and consumers value sustainability and resources and energy become scarcer and more expensive. Therefore it becomes interesting to develop more efficient technology that uses less resources and energy. '

The idea is that without government intervention, the market will find the most cost-efficient solution. In this view, the government should not support specific technologies - picking winners - but creating the conditions for the market to work properly. At the same time, energy companies expect that the government plays a(n important) role in providing long-term investment security. At the moment the absence thereof is identified as the main obstacle for investing in sustainable solutions. As the respondent of E.on puts it:

> 'we would love to invest in the Netherlands as E.on Benelux, but we have difficulties convincing our German colleagues. They make lists of the most attractive countries to invest in in Europe. Well, the Netherlands does not show up in the top ten. Therefor, they basically look at two things: One is of course profitability, they do want to make some money. But two is stability, how sure can you be that you will get your money back?'

A similar sentiment is displayed by respondents of the other energy companies, the respondent from Essent for example adds that: 'in the end, it should be left to the market, to businesses and entrepreneurs, to choose the technologies they want to pursue.' The respondent from Nuon puts the ball in the court of the economics ministry: 'the Dutch EL&I supports the idea of the market very much, taking care that the market can develop its own initiatives, but thereby it is also very dependent on those businesses.' This apparent paradox between letting the market sort out the most cost-efficient solution and looking at the government for creating a secure and long-term investment climate will be discussed more elaborately in section 3.1.

The substoryline that emerges from this section could be summarized as: 'the market is the preferred ordering principle for the energy domain and should be leading in order to achieve sustainability in a cost-efficient way.'

Substoryline IV: "energy sector should be organized at EU-level"

Most respondents argue that energy, which used to be a largely national sector, is increasingly becoming European. Therefore, it should be regulated at this level as well, thereby making use of the comparative advantages of different countries. The respondent of E.on states: 'there should be much more control from a European perspective, e.g., what happens where? We are a pure European player; we are present in many European countries. It is really inefficient when every country would be achieving its goals by itself.' GDF-Suez's respondent adds:

> ‘you have to look where to put wind turbines. Well, there where the wind blows. Where will you put solar? Where the sun shines. Where will you put gas-fired power plants? Where you have enough cooling water, natural gas resources, [and a] gas network. Coal the same: in a harbour, cooling water, possibilities for CCS, offshore. The fragmentation that is still there will hopefully continue to crumble and then we will increasingly move towards more European systems for electricity, for natural gas, for CO_2, the ETS[5], [and] hydro power.’

The substoryline in this section could be summarized as: ‘as the energy sector (increasingly) is a European sector, it makes most sense to organize it at that level as well.’

Substoryline V: “European Emissions Trading Scheme (ETS) should be leading in reducing CO_2”

The ETS is seen as the preferred instrument to get to a more sustainable energy system. According to the respondent of Eneco ‘the ETS is one of the most important drivers for renewable energy.’ The respondent from VEMW adds:

> ‘the best way to not only incentivize but also provide the possibility to [contribute to a solution] is to internalize environmental costs. An ETS provides a good model for doing so. By giving CO_2 a price, by making the right to emit CO_2 scarce, everyone will take into account the effects of sustainability when investing, next to the effects on supply security and costs.’

From this perspective, some respondents seem to prefer a single goal for CO_2-reduction at the European level to follow-up the current 20-20-20 goals, which also aims for energy efficiency and renewable energy next to CO_2-reduction.

The substoryline that becomes clear from this section can be summarized as: ‘CO_2-emissions need to be reduced and the most effective way to do so is with the European emissions trading scheme.’

3.1 Tensions within the dominant storyline

Next to the dominant storyline that is shared by most respondents, also different ways were identified in which the dominant storyline was questioned. First of all, some respondents argue that the market is indeed the preferred ordering principle but still needs work to function properly. In the respect, the respondent of VEMW states that:

> ‘There are a lot of barriers in terms of regulation, access requirements for grids and the like, which makes it difficult for new parties with new solutions to access the market, and thereby have little chance that their solution or idea will contribute to solving the energy issue.’

Regarding the role of the government, two opposing storylines emerge, which were interestingly often mentioned both by single respondents. Respondents agree that the government should create

[5] European emissions trading scheme

favourable investments conditions in order to decarbonize the energy system. However once the government then takes measures in order to create such conditions, it is criticized, because government intervention threatens the investment climate and should therefore government intervention should be minimized. Such government intervention can even lead to conflict within the regime. The clearest example, which came up in most of the interviews, is the introduction of a natural gas and coal tax[6]. In the spring accord (2012), the Dutch parliament reached an agreement of which introduction of a coal tax was part. Interestingly this coal tax was both lobbied in favour and heavily opposed by some of the organisations associated with the Dutch energy regime. An unexpected coalition of companies with interests in natural gas (Dong Energy, Eneco and Shell) and the environmental NGO Stichting Natuur en Milieu lobbied in favour of the coal tax[7]. Out of sustainability concerns, according to the press release. The traditional energy companies that own coal fired power plants were not amused. In this context, the respondent of E.on states:

> 'what frustrates us is that the same MPs that shout that the investing climate should provide long-term stability, now do this. […] So, we feel betrayed[8]. For us this is a clear example of changing the rules during the game.'

Interestingly, the respondent from the Ministry of EL&I agrees with the respondent of E.on:

> 'A stable investment climate is crucial. Everyone always looks at the government and says the Dutch government has had shaky renewable energy policy for years. But the [political] parties that say this are the same that suddenly introduce a coal tax. This time it is on coal, but still it is unreliable policy. That does not help for the investing climate, and that does not look good on the Netherlands.'

The respondent from Energie-Nederland shows that the coal tax leads to discussions amongst its members:

> 'We had internal discussions about it. Companies that had no coal fired power plant said: 'well it doesn't really affect us, so we do not really care.' Some even said: 'well maybe it even benefits us, because our gas fired power plants are standing idle at the moment' […] so they thought it would not be so bad to introduce a coal tax.'

From the interviews it becomes clear that 'discussion' is an understatement. The traditional energy sector and especially gas fired power plants are in trouble at the moment. The marginal costs of gas

[6] These taxes formed part of the Spring Agreement, which was reached in a very short period after the governing coalition stepped down on the 23rd of April 2012, in order to carry out austerity measures until new elections would take place.
[7] Dong Energy, Eneco, Shell and Stichting Natuur & Milieu support coal tax: http://corporatenl.eneco.nl/nieuws_en_media/Persberichten/Pages/Kolenbelasting-maakt-Nederlandse-economie-sterker-en-duurzamer.aspx
[8] 'We voelen ons daardoor wel wat in het pak genaaid'

fired power plants are higher than most other power plants. Therefore, gas fired power plants are standing idle. The respondent from Nuon states:

> ‘when cheap solar and wind are imported [from Germany] our gas fired power plants are just not ‘in the money’ anymore’

It seems that in response actors with natural gas interests are repositioning themselves. The respondent of Delta observes:

> ‘natural gas is being presented as a preferable transition fuel because of the low CO_2-content and the possibility for flexible application.’

Moreover, the reactions to introduction of the coal tax give the impression that some respondents wish to separate what they refer to as the market from democratic processes and even put the first above the latter. As the respondent from Essent puts it:

> ‘you lose your faith in the market when there are too much interventions and market-undermining activities.’

3.2 New developments that challenge the dominant storyline

Next to tensions within the dominant storyline and regime internal struggles over specific measures, new developments which respondents had trouble to fit to the dominant storyline were observed. Three such developments came up repeatedly during the interviews, namely Germany’s Energiewende, decentralization of the energy system and new players entering the energy market. The storylines on these developments often diverged between different respondents and will be discussed in more detail below.

Most respondents referred to the significant changes that are taking place in Germany’s energy system. The respondent from GDF-Suez for example said:

> ‘I was overwhelmed by what has happened in Germany the last two years, that was above all expectations. So maybe a whole new paradigm is emerging’

Also other respondents mentioned the Energiewende, often questioning its direction and swiftness and already see these developments affecting the Dutch energy system. However, respondents had different ideas on what the drivers for the Energiewende are, how it will develop in future and what the effects on the Dutch energy system are.

The clearest challenge which came back in almost all interviews and is difficult to rhyme with the increased Europeanization of the energy sector and the market as preferred ordering principle, is that of decentralisation of the energy system. This development and its disruptive potential are recognized by most respondents, the respondent from E.on states:

> ‘I believe we realize more than anyone else that centralized electricity production is coming to an end.’

The respondent from the Ministry of EL&I tries to fit this new development within the dominant storyline:

> ‘Now we see a divergence to two systems, on the one hand more and more international, with much more interconnections, even larger power plants, especially for industry, I mean Hoogovens[9] will never run on solar panels so to say. And on the other hand we see much more decentralized, small-scale.’

However, there are a lot of questions and doubts around its impact. A couple of respondents discussed the possible need for adaptation of the current market model in order to accommodate decentralized energy production. One of the respondents goes even so far as to fundamentally question the energy market model as it exists at this moment.

Connected to the decentralisation trend is of that of new players entering the energy domain. The respondent from the Ministry of EL&I welcomes this development and states that:

> ‘You see that in the market a lot of players, a lot of initiatives originate to stimulate decentralized energy. Cooperations develop, all kinds of small companies spring up like mushrooms, local governments that want something.’

However, the respondent from Essent sees this fundamentally differently, he proposes to:

> ‘keep everything that is decentralized outside of the market. Then you at least let the market do its work. […] you should not pollute the market with that.’

Next to new players active in decentralized energy supply, the respondent from Essent observes:

> ‘Things are really changing, the market is changing, different players. IKEA is building more wind turbines than RWE worldwide, Google more solar panels than a lot of others. There are a lot different new players in the market, then what is still the sector? What connects us?’

The respondent from VEMW also sees a role for other players from outside the industry or energy sector: ‘Think about the IT-sector or companies that are very good at marketing products or reaching consumers. Why could companies like Google or Apple not play a role?’

[9] A large steel producer in the Netherlands

As the quotes show, these new players in the energy domain can be new companies, citizen initiatives in the form of energy co-operations or large multi-nationals from other sectors, such as IKEA and Google getting active in the energy sector. Incumbents in the energy sector see the involvement of large players from other sectors in the energy sector as more disruptive than the development of small-scale local energy cooperatives.

4. Discussion

First of all, there is an on-going discussion in transitions literature whether it is possible to identify an on-going transition or if this is only possible in hindsight (Verbong & Loorbach, 2012). Throughout this research it became clear that ‘energy transition’ as a concept has established itself in the discourse of various influential actors involved in the Dutch energy system. The concept was purposely avoided by the researcher in the questionnaire but was brought up spontaneously in most interviews. The concept is used by influential actors in the Dutch energy system in order to frame the changes that are coming their way in their storylines about the future. This means that the concept has value for these actors to explain the dynamics in their sector. However, while the concept is used by different actors, they often mean different things with it.

Another challenge in transition studies is to assess which phase an on-going transition is in. The multi-phase concept was developed to describe transitions in time, speed and size and distinguishes four phases: the predevelopment, take-off, acceleration and stabilization phase. The transitions literature suggests that in the acceleration phase changes become visible at the systems-level. The results of this research show that different regime actors use the concept ‘energy transition’ to refer to fundamental changes that are taking place in the energy domain. Therefore it could be concluded that the energy transition has reached the acceleration phase, which seems to underline the findings of various transition scholars studying the energy sector (cf. Verbong and Loorbach, 2012).

This research shows that the tensions within the dominant storyline and challenges to it by newly emerging developments can lead to regime internal struggles and conflicts. This is illustrated by the example of introduction of a coal tax. One could argue that the dispute over the coal tax is a sign of the regime positioning itself in the face of niche-pressures. The problem with this explanation, however is that the observed reactions were not uniform throughout the regime, rather one part of the regime, which is more involved in natural gas, seems to abandon another part of the current regime – coal – to incorporate renewable energy in its repositioning efforts. The result seems to be regime internal struggles. These findings underline the inadequacy of viewing the regime as a uniform entity that actively resists change. It shows that at least some regime players are actively repositioning themselves towards the changes they observe in the energy system. One part of the regime, namely that involved with natural gas, frames natural gas as a “friend of renewable energy” or “transition fuel” because natural gas is cleaner than coal fired power, but apparently also because it is difficult for natural gas to compete with coal fired power given current market conditions. In pushing this frame some actors are willing to go so far as to lobby for a tax on coal. From a transitions perspective, this is an interesting development as it shakes up long held positions and coalitions. Given the strong natural gas interests in the Netherlands, this repositioning could weaken the position of coal and strengthen the position of renewable energy. On the other hand, it could also open the door to a renewed lock-in (Unruh, 2000) in a fuel that is still fossil, i.e. it will run out in the end and also emits CO_2 , although less than burning coal.

4.1 Uncovering a new storyline for the energy transition?

This research shows that the storyline that currently dominates the energy sector is increasingly becoming inadequate to encompass the change that respondents observe in the (Dutch) energy sector at the moment. Stopping at just pointing out the difficulties in that storyline feels unsatisfactory. Therefore, in this section some discussion points are identified which could form input for a new storyline that more adequately addresses the changes respondents observe in the energy domain.

Problem perception

As pointed out in the introduction, transitions can be regarded as wicked problems taking place in complex systems. An important characteristic of wicked problems is that the nature of the problem is unclear and that the problem definition can differ according to the perspective of the observer. The main problem the energy transition aims to tackle according to most respondents is climate change. The respondent of Energie-Nederland however, observes that there are also other societal problems or needs an energy transition could cater for, such as the (re)communalization a lot of citizens are looking for. An on-going societal dialogue on what the objectives of the energy transition are and which problems it aims to solve could provide helpful in defining the problem and therefore the direction in which to look for solutions.

Changing market

As pointed out at the end of section 3.2, the respondents of Essent and the Ministry of EL&I have different understandings of what the energy market is. At the same time there are a lot of questions concerning the current market design. The market is developed based on logic of centralized energy production. With an increasing share of variable renewables the fossil market logic becomes problematic, because renewable capacity has high up-front investment costs but close to zero running costs, as opposed to conventional power plants that have relatively low upfront investment costs, but higher running costs because of necessary fuel inputs. Open discussion is needed on how to adapt the market in such a way that it continues to work under changing circumstances.

Changing roles

Another point of discussion that emerges from the interviews is that some actors are struggling with their own but also each other's roles and that of new players in the energy system. From the interviews one of the main points of concern is the changing role of authorities. Through the drives for increased Europeanization on the one hand and decentralization on the other, the role of national governments becomes less important, while to roles of European and local authorities grow. The impression the interviews give is that significant changes in the energy sector are already underway. An open discussion about the role of the authorities, especially that of the Ministry of EL&I and where the country's future economic interests might lie seems appropriate. It could also include the role other Ministries play in legitimizing the Ministry of EL&I's current position and the role of the regulator in the Dutch energy sector.

Moreover, the roles of the large utilities are discussed. Respondents of large utilities voiced their concerns about the future of their companies under changing circumstances. Some business development units are already actively looking for new ideas which could include value creation in a more decentralized energy supply, energy (efficiency) services or an active role in balancing the grid which will be fed from more distributed energy sources. In the interviews the Dutch energy sector was often positioned in between market and government. What is often overlooked in this perspective is the role a lot of citizens could and want to play in solving the problems the energy system is confronted with (see e.g. Hajer, 2011). As discussed in section 3.2 the respondent of the Ministry of EL&I sees people working together in energy cooperations as market forces. However, as cooperations not necessarily respond to market forces like businesses do, it might be necessary to (re)consider their role in shaping the future energy system and how this relates to the current constellation of market and government.

Unexpected coalitions

The last point of discussion regarding a new storyline is that a shift in discourse coalitions can be expected or is even actively pursued already. An example of this could be observed around the introduction of the coal tax, as Dong Energy, Eneco, and Shell cooperated with the environmental NGO Stichting Natuur & Milieu to advocate a coal tax. Also the respondents of GreenChoice and VEMW showed remarkable similarities in storylines where it considers improving market functioning, especially regarding access for new players. Such new (discourse) coalitions could result in unexpected dynamics and synergies which in turn could lead to creative solutions for existing problems.

However, destabilisation in the culture, structure and practices of other regime players could be observed in this research as well. The clearest example is a difference of opinion between the respondent of the Ministry of EL&I and that of a large utility on what actually constitutes the energy market. The respondent of Energie-Nederland goes so far as to question the current energy market structure in the light of an increasing share of variable renewable sources of energy. Adapting the energy market could have far reaching consequences as it is seen as such a fundamental organizing principle of the energy sector. The respondent of Energie-Nederland also observes differences of culture between younger and older people involved in energy discussions within his organization. The respondent of VNO-NCW explains that the practices of his organizations have changed considerably over time, as they increasingly cooperate with the environmental movement in their lobbying efforts.

5. Conclusion

The first conclusion of this research is that ‘energy transition’ is adopted by influential actors as a way to frame the dynamics in the energy sector. Although actors have diverging interpretations of what the energy transition entails, its use means that it has value to interpret the changes going on in the energy domain. This could be an indication that the Dutch energy transition is heading in acceleration phase, as this is the phase in which changes become visible at the systems level.

Furthermore, a dominant storyline that is shared by most respondents could still be identified, which reads ‘decarbonisation in a European market, while keeping the energy supply secure and affordable.’ However, also tensions within this dominant storyline were encountered relating to different interpretations of the energy market and the role of the government in the energy transition. Next to these tensions respondents observed new developments that have the potential to fundamentally challenge the dominant storyline, most notably Germany’s Energiewende, decentralisation of the energy system and new players entering the energy market,. Actors’ storylines on these developments diverge considerably and will still need some time to flesh out.

The diverging storylines around Germany’s Energiewende, decentralisation and new players entering the energy system show that respondents found it difficult to fit these to the dominant storyline. Actors respond to this misfit in different ways. Some develop storylines with which it is possible to combine these new storylines with the dominant one, such as the respondent of the Ministry of EL&I that observes two opposing but simultaneously developing trends of Europeanization and decentralisation. Other respondents start to fundamentally question the dominant storyline as a consequence of these new developments, such as the respondent of GDF-Suez that wonders whether a complete new paradigm is developing because of the German Energiewende.

The examples of discursive regime destabilisation that where observed in this research tend towards a kind of multi-level perspective on discursive regime destabilisation: the energy transition concept is broad and therefore easy to agree upon, even if different people have different understandings of the concept. Most respondents agree that there is no fundamental difference of opinion over the long-term goals of an energy transition (80-95% CO_2-reduction), however disagreement develops around the actual implementation of this goal. Actual discursive regime destabilisation is observed around more concrete concepts such as the energy market, or government intervention towards achieving the overarching goal, such as the coal tax.

What this research shows is that although different regime elements are still in place, such as coal fired power plants, network infrastructure, energy markets, the discourse, the 'glue' that holds these elements together and provides meaning and coherence to the different elements, seems to be dissolving. This 'discursive regime destabilisation' increasingly leads to confusion of how different regime elements and actors relate to each other and how actors position themselves in the energy domain. By exposing the internal diversity, sensitivities and internal struggles new leverage points for transition management can be identified.

5.1 Outlook

This research sheds some light on how the energy transition is understood by regime actors in the Dutch energy system and therefore gives insight in possible directions the energy transition could take. The dominant storyline that emerges from the interviews is that climate change is perceived as the main problem that needs to be tackled with an energy transition. Taking this as the problem definition leads to technical solutions such as increasing the share of nuclear power and renewables and developing carbon capture and storage for coal and natural gas fired power plants. However, some of the respondents also see other societal problems an energy transition could cater for, such as people looking for (re)communalization in which decentralized renewable energy could play a role.

New developments such as Germany's Energiewende, decentralization of the energy system and new players entering the energy market challenge the dominant storyline. This leads to 'discursive regime destabilisation', signalled by confusion, insecurity and conflict amongst regime actors. An example of confusion is the disagreement over whether new players such as energy co-operations are part of the energy market or should be left out of this market. Insecurity about the future was displayed by some respondents by stating that it is unclear which of the large utilities will still exist in 20 years from now. A clear example of conflict is the introduction of a coal tax, which was supported by regime players that are involved in the natural gas business, but would hurt those regime players that (also) operate coal fired power plants.

Regarding the future energy discourse on the one hand one could expect such instances of discursive regime destabilisation to increase when more regime players get involved in renewable energy sources, when other countries, such as Germany, develop radical policy to support this development and when niche-players continue to pressure existing constellations. This could lead to a fundamental shift in the dominant culture, structure and practices in the (Dutch) energy domain. On the other hand, regime actors could succeed in recognizing and accommodating pressures timely. After initial destabilisation, this could lead the regime to develop a new and more adequate storyline and reconfigure and restabilise around it. An example could be 'natural gas as friend of renewable energy'. If this storyline persists, coal fired power plants could be exchanged for centralized forms of renewable energy, such as offshore wind or biomass (co-firing). In this way, adapting to pressures could actually result in a stronger regime. Whatever the future brings, it implies the necessity of developing a new storyline that more adequately addresses the tensions within and challenges for the current dominant storyline.

5.2 Recommendations for further research

The results of this research imply that the energy transition is heading towards the acceleration phase. During this phase the empowered niche-regimes challenge the existing regime and changes become visible for regime actors. What this research makes clear is that in this phase a homogenous and static regime concept as is often used in the transitions literature becomes problematic. Different regime elements still exist, but the culture (interpreted as discourse in this research) that provides meaning and coherence to these elements is changing. Therefore, first steps are made in refining the regime concept, such as the ‘industry-regime’ by Turnheim & Geels (2012). This research, especially the regime-internal dispute over the coal tax, shows that differentiating the regime along the lines of compatibility with changing circumstances could be a promising option. In this case the divide was along the lines of business interests in coal and natural gas, fossil fuels with different characteristics that are more or less compatible with concerns about climate change and more variable energy sources such as wind and solar. Furthermore, it would be worthwhile to assess whether the concept of discursive regime destabilisation could be used as an indicator for the phase a transition is in. In order to be able to identify discursive regime destabilisation as an on-going process, it would be necessary to repeat this research in future. Further distinction could then be made in the different patterns in and drivers for discursive regime destabilisation. In this way, investigating discursive regime de- and restabilisation could become part of the transition monitoring tool-box (cf. Taanman, 2012).

Also investigating discursive regime destabilisation around transition challenges in different sectors could yield valuable insights to further develop its theoretical fundaments. Another interesting research suggestion is to investigate regime ‘dropouts’, actors that have been part of the (energy) regime for a long time, but lost faith in the dominant storyline or saw different opportunities because of on-going transition dynamics. Insights from such research could provide a better understanding of how discursive regime destabilisation works and what exactly leads regime actors to lose faith in the dominant storyline.

Discursive regime destabilisation also provides interesting research and practical venues for transition management, the discipline that explores and applies possibilities for steering transitions. A better understanding of the destabilisation process could result in developing strategic interventions that make use of the identified weak points in the dominant storyline and promising emerging storylines, thereby speeding up the regime destabilisation process.

Other suggestions for further research based on this explorative venture include transnational transition dynamics. Transnational transition dynamics have not been studied in-depth so far (see e.g., Vleuten and Högselius, 2012) because systems under study are mostly limited in geographical scope to a single country, just like in this research. This research shows that the transnational transition dynamics also have a discursive component, in other words, the developments in Germany influence the both the public discourse and storylines of regime actors in the Dutch energy domain. By comparing the dominant and emerging storylines and discourse coalitions in different countries, preferably around an emblematic issue (e.g. Fukushima) a better understanding of such transnational influences could be gained.

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Spatial dimensions in an (un)sustainable transition: demand management and the restructuring of Victoria's electricity sector

Submission 314

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Spatial dimensions in an (un)sustainable transition: demand management and the restructuring of Victoria's electricity sector

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In the early 1990s the electricity system in Australia's second most populous State, Victoria, underwent a process of radical market liberalisation. At the start of this period the Victorian industry was a large, government-owned, vertically-integrated monopoly that controlled almost all aspects of electricity service provision within the State of Victoria for more than 70 years. By its close, the electricity industry was fully disaggregated and privatised; a wholesale market for electricity was established; and the roles of energy retailer and distribution network service provider were separated. Full retail contestability came into effect in 2001 and government price controls were removed in 2009.

This period of rapid change in the structure, governance arrangements and interactions between social groups presents a puzzle for scholars of sustainable transitions. Does the triumph of market logic through the unbundling of previously integrated large scale infrastructure networks and the segmentation of previously uniform and undifferentiated customer markets enable or inhibit a sustainable transition, or does it have contradictory and ambivalent effects for sustainable transformations? To what extent does the existing literature on sustainable transitions provide us with the tools necessary to draw these conclusions? What other bodies of literature might help to explain the nature and pattern of sustainable transitions through a period of intensive market-oriented restructuring?

In order to explore these questions I will examine the treatment of demand management through the early phase of market design and regulation during the restructuring of the Victorian electricity industry. "Demand management" is used as an umbrella term to encompass a range of practices that influence the consumption of electricity on the customer's side of the meter - from energy conservation to energy efficiency to peak demand management.[1]

This paper argues that the transformative potential of market liberalisation either towards or away from sustainability has been undertheorised in the sustainable transitions literature. A full exploration of market effects has been limited by the failure to analyse the relationships and networks across a range of scales. The paper builds on the growing body of work that has begun to examine the geographical dimensions of sustainability transitions. It also draws on the literature in critical geography on neoliberalisation and environmental governance to explain how scale, place, territory and networks might enable or inhibit sustainable transitions.

Part 1 describes the key features of the sustainable transitions literature and the Multi Level Perspective in particular and discusses some of the limitations of this framework in explaining the case study. Part 2 turns to the critical geography scholarship on the socio-spatial dimensions of neoliberalisation to argue that a more sophisticated understanding of scalar structuring can help in theorising the role of market liberalisation in sustainable transitions. Part 3 summarises the case study of the restructuring of the Victorian electricity industry and describes the different approaches to the governance of demand management at State and national levels through the restructuring process.[2] It shows how niches at both levels developed divergent approaches to demand management and a struggle ensued across the different scales of governance. The nature of this struggle is described and the key drivers of the market-oriented approach to demand management that prevailed are analysed. Part 4 closes with some preliminary conclusions about the implications of the case study for analysing sustainable transitions.

Part 1 Sustainable Transitions and the Multi Level Perspective

The sustainable transitions literature focuses on significant transformations in socio-technical systems, which are understood as “a cluster of elements, including technology, regulations, user practices and markets, cultural meanings, infrastructure, maintenance networks and supply

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[1] For the purposes of this paper distributed generation is excluded from the definition. The reason for this is that the focus of this research is mainly on electricity consumption practices.

[2] The Commonwealth of Australia was formed in 1901 when six independent British colonies agreed to join together and become states of a new nation. Under the federal system of government that was created powers are divided between a central government (the Australian government) and individual states. The Australian Government, sometimes referred to as the Commonwealth Government or the federal government, passes laws which affect the whole country. The States retain the power to make laws relating to the supply of energy.

networks" (Geels, 2004, Rip and Kemp, 1998). Sustainability transitions extend beyond periodic disruptions to the flow of activities resulting in the rearrangement of configurations *to* "long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard et al., 2012). Energy efficiency, energy conservation and peak demand management by end users have come to occupy a privileged place in discourses of sustainable consumption (van Vliet et al., 2005, Spaargaren, 2009, Southerton et al., 2004). Their attraction from a sustainability point of view lies in their ability to meet the service requirements of end users without the need for further expansion of supply (generation, transmission and distribution) with its attendant environmental externalities (pollution, embodied energy of heavy infrastructure and land use practices).

The integration of demand management practices into systems of electricity provision can be regarded as an important indicator of progress towards a sustainable transition. Given the unchallenged dominance of centralised supply-side patterns of infrastructural developments until the 1970s, the widespread enactment of demand management practices in electricity service provision would constitute a major shift or system innovation. Consistent with Geels and Schot's (2010) characterisation of transitions, the development of demand side management techniques involves the co-evolution of multiple regimes (policy, technical, socio-cultural environmental); novel modes of interaction between end users, firms, regulators, technology specialists and technology; change that can be described as radical and disruptive in nature; and a slow evolution with processes of change unfolding over decades rather than years (Geels and Schot, 2010). However, the sustainable transition to widespread and effective demand side management has not yet eventuated with DSM being one of the significant "unresolved problems" of Victorian and national electricity supply. The MLP analysis can be used to try and explain why a regime that has undergone a number of seemingly disruptive changes in the last 30 years has failed to achieve a sustainable transition in the field of demand management.

Within the sustainable transitions literature the multi-level perspective (MLP) has emerged as the approach most attuned to explaining the nature and patterns of long term changes in particular industries or sectors (Geels, 2004, Geels and Schot, 2007). MLP explains technological transitions in terms of the interaction between different levels: niches, regimes and landscape. Niches are characterised by a certain freedom from the rules of the existing regime. They are creative opportunities for learning and innovation which are characterised more by uncertainty and exploration than clear cut rules. The challenge for the niche, according to the MLP model, is to try and create novelties that break through into the existing socio-technical regime.

Regimes are made up of rules and practices that are embedded in institutions and infrastructures and guide the behaviour of actors in a relatively stable way (Rip and Kemp, 1998) 338). Regimes occupy an intermediary space between the more fluid and dynamic micro level of the niche and the higher macro level of landscape developments. The socio-technical landscape takes in cultural values such as changing norms around thermal comfort, accumulating environmental problems such as climate change, strategic political coalitions such as alliances between social welfare advocacy groups and long-term economic developments (Geels, 2004). These “exogenous forces” may come to interact with the regime and become integrated into the particular dimensions of the socio-technical regime through techno-scientific, policy, or cultural discourses, or through infrastructure artefacts, end user practices or strategic games between firms (Geels and Schot, 2007).

Interactions between the regime and the niche, or the regime and the wider landscape, can result in misalignments that destabilise the system of rules and conventions (Elzen et al., 2004). The regime acts as a configuration of interlocking relations that tends to reinforce its overarching purpose. However it is still dynamically engaged with the “outside”, making it susceptible to innovation from the niche below or broader landscape developments. Those misalignments that cannot be resolved with the existing rules, practices and relationships of the socio-technical regime result in tension and eventually disruption to the socio-technical regime. It is at this point of disruption and subsequent reconfiguration that a sustainable innovation and pathway can be forged.

<u>Market Liberalisation</u>

The dynamics of market liberalisation and the potential for market forces to shape and be shaped by sustainable transition pathways have generally been under explored in the MLP literature. In Verbong and Geels’ work on the renewable energy transition in the Netherlands, market liberalisation is mentioned but does not play a significant role in the historical account (Verbong et al., 2008). The Dutch National Electricity Law 1998 which created the framework for market liberalisation through the separation of generation from transmission and distribution, the regulation of network tariffs and the introduction of retail competition, is mentioned but its role in enabling or inhibiting innovation within the socio-technical system is underplayed. In comparison, direct government interventions via industry, energy and climate change policies are ascribed an important role in the reshaping of the Dutch energy generation portfolio (Verbong et al., 2008).

The processes of planning for sustainable transitions seems to be a favoured area of inquiry in the literature. For example, Truffer *et al* (2010) develop a method of strategic planning that applies reflexive governance and participatory practices to promote improved environmental decision making in the area of sanitation (Truffer et al., 2010). While the interest in centralised planning for low carbon transitions may reflect the specific political and institutional context in parts of Northern and Western Europe, in other settings, such as Australia, the creation of wholesale and retail markets has reconfigured planning processes and decentralised decision-making for key infrastructure areas such as electricity. The governance relations that have emerged out of market liberalisation in Australia have created a whole new set of socio-spatial relationships that undermined previous models of centralised planning and heavily influenced the trajectory of sustainable initiatives. As a consequence, without a more in-depth theory of the role of market liberalisation in sustainable transitions the MLP literature fails to address an entire generation of policy initiatives.

Joachen Markard and Bernhard Truffer (2006) do tackle directly the pathways for innovation in large technical systems under conditions of market liberalisation (Markard and Truffer, 2006). Drawing on the MLP framework the dynamics of liberalised markets are viewed by them? as external stimuli that may lead to the opening up of previously closed technological regimes and create opportunities for innovation (Truffer et al., 2010). The selection criteria applied to innovations are affected by new entrants to the market, grid access for independent power producers, greater choice of products and services for consumers and regulation of network tariffs. Taking the stationary fuel cell as an example of a radical innovation, Markard and Truffer argue that market liberalisation contributed significantly to creating the conditions necessary for incumbent electric utilities to develop new markets for the technology and engage in new learning processes (Truffer et al., 2010) at 622. The introduction of competition within the industry and the contestability of customers created a greater appetite for risk amongst firms which translated into broader investment criteria and more robust innovation strategies. New networks and alliances were pursued and greater rewards were to be found in the promotion and diffusion of radical new technologies (Markard and Truffer, 2006) at 623.

Markard and Truffer are careful not to overstate the implications of their findings from qualitative research in the Netherlands, Germany and Switzerland. They note that market liberalisation cannot be regarded simply as a driver of new technologies rather they more cautiously argue that it is “a driver that transformed the basics of search and innovation processes and may thus weaken prevailing technological regimes” (Markard and Truffer, 2006) 624). They warn that changes observed may be a response to the creation of opportunities within a new market that could soon narrow as mergers and acquisition lead to greater concentration of ownership and incumbents engage in less risky innovation processes.

For Markard and Truffer market liberalisation is framed and analysed in the following ways. Firstly, the opening up of markets is seen as external to but interacting with the operation of the technological regime. Secondly, market liberalisation is regarded as worthy of analysis because of the way it affects the embedding of particular technological artefacts within society. Thirdly, market liberalisation is treated as distinct from environmental governance. Fourthly, market liberalisation is analysed mainly at the scale of the nation state with little attention paid to the multiscalar manifestations of liberalisation.

These characteristics, I argue, have understated the potentially transformative effects of market liberalisation either towards or away from sustainability. They inhibit full exploration of market effects by ignoring the subtleties of scalar differences and in so doing conceal the relationships and connections within networks across a range of scales (Coenen and Truffer, 2012). The levels within MLP analysis do not correspond to specific geographical scales, but to the socio-cognitive maturity of a socio-technological system (Coenen et al., 2012). In so doing, the construction of scale, place, territory and networks and the work they do in enabling or inhibiting sustainable transitions are left out of the narrative.

This paper follows in the footsteps of a growing body of work that has begun to examine the geographical dimensions of sustainability transitions (Raven et al., 2012, Späth and Rohracher, 2012). Coenen *et al* call for a greater focus on the territorial embeddedness of sustainability transitions as well as a more relational approach to conceptualising scale. Lawhon and Murphy (2011) draw on political ecology and its concerns with power relations in environmental decision making to show the uneven effects of environmental decisions across different scales. They warn against over reliance on any single driver of environmental degradation and extend their focus to a broader network of actors (both human and non-human) to explain transitions. Hodson and Marvin (2012) turn their attention to cities as productive sites of interaction between national, regional and local scales in the coordination of low carbon transitions. National energy and environmental priorities have to be rescaled to fit the particularities of the urban context. Through the transition, energy regimes that are not organised on a city-regional scale have to adapt and be adapted to.

Working in a similar vein I will now turn to the extensive body of literature within critical geography that examines the spatially uneven patterns of neoliberalisation and draw on this to address some of the gaps in MLP's approach to market liberalisation.

Part 2 The Spatial Dimensions of Neoliberalisation

There is a large body of work within critical geography that seeks to theorise the key features of neoliberalism and to understand how neoliberalism interacts with environmental governance and politics (Castree, 2008a, Castree, 2008b, McCarthy and Prudham, 2004, Heynen et al., 2006) Close attention is paid to the historical and geographical specificity of neoliberal processes and the effects produced across different scales (McCarthy and Prudham, 2004, Larner, 2003, Peck and Tickell, 2002, Jessop, 2002).

Recent research has defined the following features of neoliberalism: the privileging of private ownership of property over public ownership leading to the privatisation of long-held state owned assets; the promotion of consumer sovereignty whereby consumers are depicted as being "free to choose" what they consume contingent upon having the financial resources at their command; the penetration of pricing to a range of objects and services that were previously unpriced or not the subject of market exchange (e.g. carbon dioxide); the construction of state and market as distinct spheres and the "roll back" of state involvement in the market; the related re-regulation or reanimation of state activity to manage the worst excesses and deleterious social effects of the neoliberalisation process; the use of market proxies in remaining public services, making the public sector "benchmark" itself to what is presumed to be a more efficient and competitive private sector; and the deployment of civil society actors as "flanking mechanisms" to perform the services that were previously undertaken by the Keynesian welfare state (Peck and Tickell, 2002, Jessop, 2002, Castree, 2008b).

The Victorian process of reform of the electricity sector displays many of these hallmarks of neoliberalism. However, the scholarly literature on neoliberalism makes clear that there is no such thing as “textbook” neoliberalisation in practice (Brenner, 2002). While the Victorian experience clearly subscribes to the broad brushstrokes of a neoliberal framework, empirical research shows that regional, national and local dynamics play a constitutive role in the shape and style of the restructuring project (Brenner and Theodore, 2002). These, in turn, are produced through enduring institutional relations, political struggles, material landscapes and governance practices. The phrase “actually existing neoliberalisms” has been used in critical geography literature to draw a line between the claims of neoliberal ideology and the messy, context-rich, contradictory outcomes that are produced (Brenner, 2002).

Market oriented regulatory restructuring has had distinct spatial dimensions as particular territories, places and scales are remade as productive forces (Smith, 1984, Brenner, 2002, Harvey, 2006). Far from being an “exogenous background” upon which regimes and niches interact, market restructuring creates the socio-spatial conditions which can lead to a scaling up of a niche or the uneven distribution of sustainable outcomes (Lawhon and Murphy, 2012). Projects of neoliberalisation interact with existing institutional arrangements to produce new modes of regulatory reorganisation at different scales. Path dependency is a crucial dynamic in the collision between new market logics and pre-existing institutional practices. MLP approaches have been particularly focused on the interlocking practices that stabilise socio-technical regimes and reinforce path dependency. A more spatially-oriented analysis adds to this by drawing attention to how aspects of scale or territory can sometimes exercise powerful structuring effects upon patterns of neoliberalisation.

A geographical perspective can also assist in identifying the interactions between new forms of environmental governance and market liberalisation rather than treating these as distinct processes. Environmental policy cannot be taken for granted as a separate sphere of policy making that intervenes in an increasingly liberalised market. In the Australian context neoliberal ideologies gave rise to new forms of market environmentalism which created hybrid socio-spatial arrangements through which environmental objectives were expected to be achieved (Bulkeley, 2005). For example, the environmental benefits of demand side management practices were to be achieved not through integrated planning processes and the establishment of utility programs targeted at end-user groups, but through the decentralised workings of the market. Demand side management was reclassified as a commercial rather than a consumer service obligation, and was removed from centralised institutional control at the State level and devolved to localised interactions between retailers and consumers.

This deliberate re-scaling of environmental governance created a new set of problems from a sustainability perspective. The implementation of cost-reflective pricing and the introduction of metering technology that provided pricing information to consumers became a precondition for effective demand side management and hence effective environmental governance. The scale of action was intended to move further and further away from the State, to coordination at the local individual and enterprise scale. In this way, environmental politics and governance have become active sites for the extension and deepening of marketisation (Heynen et al., 2006). Environmentalism and neoliberal ideology have incorporated elements of each other to produce a hybrid form of market environmentalism that has served to consolidate the market liberalisation agenda (McCarthy and Prudham, 2004).

I will now turn to the case study out of which many of the reflections on the limitations of the MLP approach have emerged. The case study shows how the transition to more sustainable demand management practices through the process of market liberalisation and regulatory restructuring of the Victorian electricity system was a highly contested, multi-scalar process that is not easily explained using an MLP framework.

Part 3: Demand Management and the Restructuring of the Victorian Electricity Sector

Until the late 1980s the role of the Australian Commonwealth (national) government in electricity planning and policy was negligible. The States of Australia (seven in total) exercised control over electricity systems within their territorial boundaries and engaged in State to State cooperation on a needs basis. The dynamic between the States' electricity bodies has been described as a battle between "warring tribes", reflecting the historically difficulties in cooperation across State boundaries (Booth, 2000). In the late 1980s this began to change when the Commonwealth and State governments created a new vehicle for collaborative federalism, the National Grid Management Council (add date).

The Council was designed to encourage and co-ordinate the most efficient, economic and environmentally sound development of the electricity industry in eastern and southern Australia. Through the NGMC, extensive explorations were undertaken of how to progress demand management within a competitive national market framework. None of this work found its way into the final market design and regulatory framework enacted in Victoria with the commencement of National Electricity Market. To understand why, we need to explore how the niche within the NGMC on demand management interacted with a competing niche within the Victorian State government that was pursuing an aggressive neoliberalisation agenda for the electricity industry in Victoria. The interaction and struggle between the two scales of governance produced a new socio-spatial arrangement for demand management that was characterised by a shift towards decentralised decision making by individual consumers in response to price signals. These price signals were to be determined by wholesale market dynamics, light handed regulation of pricing and the risk management strategies of retail businesses. This socio-spatial "settlement" has strongly informed the pathway to a more sustainable electricity system. In the minds of key governance actors the success of demand management and a more sustainable electricity system has been yoked to the progress of market liberalisation.

First Steps for the Commonwealth

In 1986 Dr Alan Moran was appointed to head the national Labor government's newly created Business Regulation Review Unit, a small research team of just four people that reported to the Industry Committee of Cabinet. Moran did not pretend to be the disinterested non-partisan official that the Public Service Code idealises. Instead he had a very strong belief that less rather than more government intervention was the key to unlocking the nation's wealth.

Moran led a small inquiry into the impact of charges for government supplied goods and services on the competitiveness of Australian industry that focused on the Electricity Supply Industry (ESI) (Industries Assistance Commission, 1989). The report was the first major intervention at the Commonwealth (Federal) level into the debate on the need for reform of State electricity government trading enterprises. Moran says that the focus on the ESI was inquisitive rather than part of a strategic agenda for major industry reform [Interview with Dr Alan Moran 2012].[3]

[3] The inquiry was critical of under utilisation of capital resulting from inaccurate forecasts of future demand and over investment in generation. It also argued that tariff structures that reflected social policy and regional development objectives imposed a burden on commercial and industrial customers. The report argued that exposing government owned electricity commissions to commercial disciplines and competitive pressures would have national benefits: efficiency improvements could expand annual output by $980m, increase disposable income by $150 per household, lower income taxes by 1.3%; and create 2,800 extra

Somewhat unexpectedly though, Moran's report played an important role in concentrating the attention of the Treasurer on microeconomic reform efforts within the electricity sector. A restructure of Moran's unit saw it emerge from the shadows of the bureaucracy to become part of the Industries Commission in 1989 which fell under the Treasurer's portfolio. The Treasurer, Paul Keating, had a strong agenda of microeconomic reform designed to promote national competitiveness and which also served to raise his own profile in his quest for the Prime Ministership [Interview with Don Russell 2012]. Keating identified State Electricity Commissions as barriers to his microeconomic reform agenda and, in the August 1989 Budget speech, announced a full Industry Commission inquiry into the performance of the electricity sector.

The Industry Commission report was a major circuit breaker in debates about the future of the electricity supply industry (ESI). The Commission, although housed within Treasury, was an independent advisory body established under statute (Productivity Commission., 2003). Its Reports had an "independence" that gave them legitimacy beyond the political debates of the day. The IC inquiry delivered its robust findings on the ESI in May 1991, recommending far reaching structural reform, privatisation and the introduction of competition into generation (Industry Commission, 1991). The report highlighted the national implications of inefficiencies at the State level and the need for inter-governmental cooperation. It proposed the creation of commercial incentives for public utilities to promote efficiency: strategic objectives should be confined to commercial performance and should not stray into community service obligations. The IC recommended the introduction competition between electricity and other fuels; between states via interconnection of grids; competition from private generators and competitive tendering for the supply of new infrastructure such as power stations and transmission/distribution network extensions (Industry Commission, 1991, 109).[4]

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jobs INDUSTRIES ASSISTANCE COMMISSION 1989. *Inquiry into Government (Non-Tax) Charges: The Electricity Supply Industry in Australia*, Commonwealth of Australia, 17 March 1989..

[4] Interestingly, the report did not mention retail competition despite the fact that that it had been canvassed in a New Zealand Inquiry just two years earlier ELECTRICITY TASK FORCE NEW ZEALAND. September 1989. Structure Regulation and ownership of the Electricity Industry Report of the Electricity Task Force .

The IC report reframed the discussion about DSM in terms of consumers as economic actors, their incentives to maximise benefits and the removal of barriers to full optimisation of individual economic benefits. The report asked:

> Should the issue of end-use efficiency be left to the energy user who might be expected to have a clear financial interest in reducing inefficiencies in use? Does DSM make sense from a utility's point of view? Why would a utility involved in selling electricity or gas wish to reduce its sales? Where if at all, do governments fit in? (Industry Commission, 1991).

In answering these questions, the IC put the energy consumer at the centre of the frame arguing,

> …since the consumer is the one who benefits from the use of energy, the consumer should be in the best position to judge which pattern of energy maximises these benefits. Hence, the primary responsibility for determining the pattern of energy use must reside with the consumer, whether this be a household or a business (Industry Commission, 1991).

The IC recommended that State government's role in DSM was the removal of institutional impediments which may constrain the full exercise of commercial incentives. Government involvement in utilities leads to distorted prices which interferes with individual decision-making. "The rationale is that the price of energy is the basis on which users judge the cost effectiveness of either an investment in an energy efficient appliance or in an alteration to their pattern of energy use…if the signals consumers receive are deficient, the decisions they make will not result in the efficient use of energy (Industry Commission, 1991 at 264)." Cost reflective pricing policies was the key tool for enabling DSM: this included both the costs of supply (institutional impediments) as well as the cost of externalities such as environmental pollution (market impediments) (Commonwealth of Australia, 1994).[5]

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[5] The Industry Commission argued that environmental externalities of energy production were best addressed through the creation of tradable emission rights or pollution taxes, not through "prescriptive" environmental standards such as mandatory minimum efficiency standards for appliance and buildings. Performance standards reduce customer choice, the report argued, and so threaten the principle of consumer sovereignty.

Federalism and Cooperation

The Industry Commission report was a blueprint for the market-oriented restructuring of electricity systems in Australia. However such structural reforms could only occur at the State level and any national reform effort required unprecedented levels of coordination between State governments. As it turned out the wheels of State-Commonwealth collaboration on electricity had already begun to turn in 1990, driven largely by the shared enthusiasm of key State and Commonwealth ministers for structural reform of government business enterprises. In 1990 the Prime Minister Bob Hawke launched a "new federalism" initiative which called for greater cooperation, improvements in the performance of government enterprises and regulatory reform (Painter et al., 1995 8). While the collaborative Federalism project began to break down in the second half of 1991 amidst leadership tensions between Treasurer Keating and Prime Minister Hawke, the States continued to plough on with their reforms to the ESI through the Special Premiers Conference process that had been established (Painter, 1998).

In July 1991, just two months after the delivery of the Industry Commission's final report, the State and Federal governments resolved at the first SPC to establish a National Grid Management Council to:

> "encourage and co-ordinate the most efficient, economic and environmentally sound development of the electricity industry in eastern and southern Australia….This represents an important step forward in advancing co-operation in the electricity industry, the absence of which has cost the nation dearly in terms of excessive generation capacity, inappropriate plant mix and inflexibility of fuel use…" [SPC Communiqué Sydney 30 July 1991] (Gallaugher, 2004, 24)

The NGMC was tasked with working out how to enact the broad agenda of increased competition in electricity generation between States, having regard to the regionalised, resource-specific and isomorphic institutional arrangements at the State level. This task was made more difficult by the fact that the NGMC was a co-operative arrangement with no legislative framework and did not create any legally binding agreement between the parties. It was governed by mutually agreed principles and recommendations. It comprised representatives from New South Wales

(Australia's most populous state), Victoria, Queensland, South Australia, Tasmania, the Australian Capital Territory and the Commonwealth.[6]

The NGMC worked slowly but steadily through this cooperative process to establish the arrangements necessary to develop an interstate transmission network. The main goal was to try and promote transmission and generation planning that operated beyond the geographical boundaries of the state (Gallaugher, 2004). A National Grid Protocol (1992) established the rules, responsibilities and technical requirements for access to the grid to trade in bulk electricity. The objectives were to explicitly balance economic, technical efficiency and environmental objectives for the ESI. The Protocol went even further and sought to "provide a framework for long-term least cost solutions to meet future power supply… *including appropriate use of demand management*" (National Grid Management Council, 1992).

The NGMC was overseen by a group of four senior industry staff and public officials from NSW and Victoria. The group was heavily engineering focused, but included one economist who had worked for the NSW state-owned electricity enterprise. One of the engineers was a well-respected Victorian utility manager who had been instrumental in the establishment of the Victorian State Electricity Commission's pioneering work on demand management.

The Ambitious Victorian Reforms

As the NGMC process evolved at a gradual pace, a critical development in Victorian State politics changed the ambition of the reforms to the electricity industry at both State and national levels. The Liberal/National Party, led by Jeff Kennett, won a landslide victory in late 1992 and came to power on a platform to restructure state owned industries. The electricity industry, the largest and most powerful government enterprise in the State, was to the first to be restructured. To reach a point of such bold and unprecedented reforms a great deal of behind the scenes work had been done by the Liberal party while in opposition with key protagonists of neoliberalisation. Michael Porter, a University academic and long-time critic of the Victorian State Electricity Commission, convinced Dr Alan Moran to leave Canberra and join a sub-unit of a think tank called the Tasman Institute to work on environmental economics. The unit sought and received funding from a number of large mining and resource corporations including BHP and Xstrata. The Tasman Institute had links in New Zealand where marketisation and privatisation was one

[6] Western Australia and the Northern Territory had grids that were not interconnected with the other States. Unlike with Tasmania which later became interconnected to the mainland through an underwater high voltage cable, there were no plans for interconnection.

step ahead of Victoria and provided an important channel for the free flow of ideas between neoliberal reformers on both sides of the Tasman.

Through the Tasman Institute an initiative called *Project Victoria* was established to produce in-depth analyses and proposals for improving efficiency and productivity in the ESI (Tasman Institute, 1991). The *Project Victoria* report into the electricity industry largely followed the recommendations of the Industry Commission, providing a more detailed strategy for phasing in the reforms. The initiative, funded by business organisations including the Victorian Chamber of Commerce, the Farmers Federation, the Chamber of Manufactures, went on to be a critical influence upon the Liberal Party in opposition.[7] It became the basis for the Coalition pre-election energy policy "Energy to Grow and Prosper" (Liberal Party of Australia. and Victorian Division and National Party of Australia., 1992).

Key to the reform efforts was the role of the Treasurer, Alan Stockdale, who had an unwavering commitment to restructure the electricity industry. Stockdale, while in opposition, had spent time in the UK at the London School of Economics studying the electricity privatisation process. He established a study group that met regularly for 12 months in the lead up to election victory. This group "dissected in great detail" the performance of the SECV against utilities in other states, focusing on costs of production in generation, debt levels, industrial relations and transmission and distribution (Booth, 2000, 45-6). The group went further than Project Victoria in exploring the potential of retail competition and proposed shifting the SECV's obligation to supply to retail franchisees [46]. For Stockdale, wholesale change to the structure and ownership of the industry was seen as the only way to disentangle the provision of electricity from its non-commercial, public policy objectives [Interview with Geoff Swier, 2012].

A special unit called the Electricity Supply Industry Reform Unit (ESIRU) was established in the Treasurer's Office. The Unit was staffed by non-public servants and non-SECV staff who were employed on fixed contracts - a highly unusual practice within the Victorian bureaucracy. Faced with considerable resistance to the reform proposals by the existing regime actors, namely the senior management of the SECV, ESIRU instituted the "Status Report" process. Whereas previously SECV staff had exercised firm control over industry reform proposals, ESIRU gave this role to external consultants who were paid to produce "Status Reports" on 24 different

[7] See Fairbrother, P., Svensen, S., and Teicher, J. 1997. 'The Withering Away of the Australian State: Privatisation and its Implications for Labour'. *Labour and Industry* 8 (2); Stockdale, A. 1999. 'The Politics of Privatisation in Victoria'. *Privatisation International* November. Tasman Economics. 2002).

industry topics. The senior management of each of the corporatised arms of what was the SECV had a limited time within which to respond to these reports. It was through this process that the SECV and the market reformers contested their different visions for the electricity industry. A key architect of the reforms from ESIRU described this as a deliberate process to “stir things up”, that is to send a clear signal to the regime actors that a radical rather than an incremental pathway to change was underway [Interview with Geoff Swier, 2012]. The government engaged in a process of conflict, contestation and struggle to achieve its goal of market restructuring. A key strategy was to open up multiple fronts for reform and to set extremely tight deadlines, minimising the opportunity for drawing out discussions [Interview with Geoff Swier, 2012]. Consultants such as London Economics, Tasman Institute, Fay Richwhite and Potter Warburg reviewed the performance of the ESI and their advice provided the basis for government decisions. Most of these key decisions were made by Stockdale and taken to Premier Kennett for approval after which they went to Cabinet for rubber stamping [Interview with Geoff Swier, 2012].

With Stockdale firmly in control of the electricity reform agenda, the regulation of the State industry and matters concerning social and environmental protection were given to the Minister for Energy and Minerals, Jim Plowman, a National Party Lower House member. Under the advice of Dr Alan Moran, who had moved from the Tasman Institute to become the Deputy Secretary for Minerals and Energy, the government quickly moved to shrink the role of the state in energy efficiency policies and programs [Interview with Ian Porter, 2012]. Government insulation regulations were dismissed as distortionary and the body designed to coordinate energy efficiency programmes, Energy Victoria had its funding dramatically reduced. Within the bureaucracy a clear segregation was made between energy and climate change/environmental policy. Despite acknowledgements of the environmental impacts of the electricity industry in government publications there was a clear view that market reforms and clearer price signals were the solution to most efficiency problems, including energy efficiency (Office of State Owned Enterprises., 1994). The restructuring of the industry was organised around narrow objectives of economic efficiency with no scope to include environmental objectives in the market design [Interview with Brian Spalding, 2012].

Divergent approaches to Demand Management at Different Scales

The Victorian government’s reform efforts were primarily focused on labour and capital efficiencies on the supply side [Interview with Geoff Swier, 2012]. There was a belief that the introduction of a competitive electricity spot market would reveal a more accurate value for electricity and, under the right conditions, drive demand management by large customers. Retail competition, which emerged as a later development in the reform process, was considered to be the vehicle through which small to medium consumers would exercise their sovereignty creating opportunities for demand management offerings from retailers.

The NGMC, on the other hand, saw greater challenges in trying to incorporate the demand side into the competitive electricity market and established an informal working group of DM practitioners from around the country culminating in the publication of *Demand Management Opportunities in the Competitive Electricity Market* in June 1994. The "Yellow Report", as it was known, recognised the importance of fully integrating DM into the structure of the competitive electricity market. The report found that,

> experience overseas has shown that DM needs to be integrated into the industry structure at the same time as the new structure is being development. In all other countries which have undertaken similar ESI restructuring, attempting to overlay DM at a later stage has proved to be very difficult (National Grid Management Council, 1994, 4).

The Yellow Report argued that with the onset of competitive market reforms DM faced a fork in the path: retailers could either become low cost commodity providers or energy service companies providing a range of energy services. The path taken depended on early decisions about market design and regulation. If the first path was chosen then retailers would find it hard to share in the benefits of demand side investments. With customers able to switch between retailers there would be little incentive for retailers to invest in DM measures that had anything beyond a short term payback. With margins so fine retailers would become more risk managers than sales people: DM programs requiring more than average levels of customer service would be seen as a liability rather than a benefit. On the other hand, if retailers focused on the efficient delivery of energy services then the transfer of electricity to customers became only a part of their business model. Retailers would be actively involved in managing their customers' energy use, which could involve energy efficiency, microgeneration, hedging price risk in financial markets, depending on what was the least cost mechanism (National Grid Management Council, 1994). In order to try and move towards an energy services model the financial interests of the retail suppliers would need to be tied to the satisfaction of customer's needs. Incentives would have to be appropriate to overcome a number of barriers, most notably the high transaction costs when dealing with small customers and the low priority accorded to energy supply by the majority of retail customers.

The report identified a role for integrated resource planning in the initial stages of establishing the competitive electricity market. Centralised planning was seen as being ultimately incompatible with the market-driven approach to sourcing new generating capacity. As a transitional measure, however, the authors proposed introducing a national demand management auction.[8] The alternative (less preferred) proposal was more prescriptive with all participants in the electricity market submitting an annual detailed integrated resource plan to a national regulator who would make a decision as to the least cost outcome for future planning. The report also found that network regulation would be necessary to incentivise DM and overcome the short term loss of revenue that networks experience due to load reductions.[9]

The NGMC's willingness to explore innovations in market design and regulation to enable demand management in the competitive market set it apart from the Victorian government's reform process. Through the Yellow Report the NGMC created a forum for a growing community of demand management professionals to articulate the need for a strategy that went beyond pricing reform and retail competition. The Report argued that the unique characteristics of electricity and the nature of the industry were such that the theories of perfect competition – a large number of sellers, a homogeneous product, perfect mobility of resources and perfect knowledge on the part of buyers and sellers of all alternative opportunities – were not only impossible but potentially inferior as a model of economic and energy efficiency. Cost-reflective pricing reforms would have limited impact on end use market barriers and were seen as a necessary but insufficient condition for achieving end-use efficiency (National Grid Management Council, 1994). The challenge was to move away from esoteric pronouncements on the "science"

[8] An independent body would analyse and assess data on long term electricity supply and demand, and then make a recommendation to government on the funding required to achieve the desired level of demand measures. The funds would be used to pay for cost-effective demand management programs that were selected through a public auction process.

[9] Three mechanisms were proposed to improve the commercial viability of energy efficiency to networks: 1) the levying of a fee on all participants in the wholesale market and the establishment of a fund to defray the cost of energy efficiency In the industry; 2) a mechanism that allowed retailers to pass through the costs associated with energy efficiency - such a mechanism would require a regulator who could approve programs based on an agreed upon set of criteria; 3) a revenue regulation mechanism that decoupled utility profits from electricity sales volume. Such a mechanism has been used in California and guarantees networks revenue irrespective of reductions in customer loads.

of price-based competition to more qualitative judgments about how to achieve demand management under conditions of uncertainty and risk, rapid technological development and the unique characteristics of energy consumption patterns.

The re-scaling of the NGMC and the triumph of the Victorian reform process

None of the proposals for enhancing the role of demand management in the design of the competitive market came to fruition. Indeed, the work of the NGMC eventually became largely subsumed within the Victorian government's restructuring timetable and agenda in what can only be explained as an inter-scalar struggle for control over design and governance of the market.

As the NGMC and the Victorian processes progressed, internal competitive power pools were emerging in the NSW and Victorian generation sectors. From early 1992 Pacific Power introduced ELEX - an internal Electricity Exchange - which required each of their power stations to compete for dispatch. This was considered very successful in terms of driving operational efficiency at the generation level and in 1992 Victoria began to experiment with a different model for competitive power pooling, Vicpool (Gallaugher, 2004). Elex and VicPool were examples of practical actions designed to try and move towards the goal of competition within generation. The pooling mechanisms provided a great deal of hands on experience and trial and error testing that proved particularly useful to the ambitious reform agenda of the Kennett government when it came into power just six months later.

Consistent with the strategy of rapid and widespread reform, Stockdale and the ESIRU team set an aggressive timetable for the privatisation of Victoria's electricity assets. A precondition for privatisation was the establishment of a robust wholesale market. It was argued that potential investors in the generation assets and banks needed to know the details of the design of the market so as to be able to assess risk [Interview with Neville Henderson, 2012]. Key reformers within Victoria, such as the head of ESIRU Peter Troughton, indicated a clear preference to proceed on their own with a Victorian-only spot market for electricity. There was a concern that Victoria's restructuring process would be de-railed by a national electricity market that they could not control.

This requirement for certainty by investors and Stockdale's unwillingness to postpone the sale of assets for fear of losing reform momentum created a problem for the NGMC. There was a strong view amongst regime actors within the electricity industry itself that a national process would be the best way of achieving the microeconomic reform goals of improved competition and efficiency. In the contest of wills that ensued the NGMC made a strategic compromise: in order to gain the involvement of Victoria in the creation of a national market they would cede a degree of control over the market design to Victoria. The NGMC adjusted away from its original goal to enable competition for generation between States through the creation of a national grid and improved trading arrangements, and in February 1994 became enrolled in the task of establishing a national market for electricity to meet the Victorian privatisation deadline [Interview with Jim Gallaugher, 2012]. The longer term planning on generation by NGMC ceased as the view within the Victorian government was that there was sufficient surplus capacity with commitments in place to carry through the transitional period.

With control of the market design reverting to Victoria, demand side management became a low order priority. ESIRU's focus was on establishing the commercial trading environment and with privatisation afoot any attempts to introduce obligations onto utilities that would limit revenue was seen as potentially harming the sale price [Interview with Geoff Swier, 2012]. The seminal document written by ESIRU,, *The Proposed Framework for a Wholesale Electricity Market* (which was informally referred to as "The Bible"), was finalised in June 1994. It was the result of furious activity by NGMC systems designers, technology consultants, and ESIRU staff over a six month period to develop the guidelines for the operation of the market. "The Bible" set out to create an efficient dispatch process and establish a wholesale price that helped players manage risk efficiently. In this 100+ page document demand management was acknowledged in one paragraph.

> There are some difficult potential problems associated with even handed treatment of supply and demand management initiatives under any price/volume based regulatory formulas…This provides strong commercial disincentives for these companies with respect to the promotion of demand management options which lead to load reductions. There are a variety of potential regulatory responses to these types of problems (Electricity Supply Industry Reform Unit, June 1994).

The paragraph is given priority status number 2. The creation of a properly functioning short term forward market was not vigorously pursued, the focus of network pricing was not set on achieving least cost outcomes, and there was no clear measurable objective for the demand side which would enable transparency and accurate monitoring. Demand management failed to find its way into the heart of national market design.

Part 4 Market liberalisation, the reconfiguration of space and the Multi Level Perspective

Both the NGMC and the Victorian government were involved in attempts at scalar transformations of the networks of electricity supply and consumption. The NGMC was a novel form of territorial governance for electricity (a national grid manager) which sought to reconfigure the supply of electricity by expanding markets across previously geographically bound limits. The NGMC's original mandate involved re-scaling electricity planning (generation, transmission and to a lesser extent distribution) from the State (regional) scale to a new national scale. The effectiveness of the national scale always rested on the ability of the States to make coordinated decisions via a new institutional arrangement, the NGMC. The case study shows that this novel governance arrangement afforded a number of opportunities for demand management. The objectives of "efficient, economic and *environmentally sound* development of the electricity industry" leant themselves towards a multi-dimensional exploration of demand management. This was further enabled by presence of a strong supporter of demand management, Jim Gallaugher, steering the NGMC work and the burgeoning of an epistemic community in demand management within state utilities that led the work on the Yellow Paper. The challenge for the NGMC was how to re-scale governance arrangements for DSM at a national level given the State's jurisdictional control of energy policy *and* the emerging dominance of the discourse of market liberalisation. The proposals in the Yellow Paper were attempts at creating a new national scale for the coordination of demand management efforts whilst promoting the decentralisation of decision making via market mechanisms.

The Victorian reform process created a radical new hierarchy of scale whereby local decentralised decisions by end users and individual firms were coordinated and scaled up through the operation of markets for electricity. Command over the planning, generation, distribution and pricing of electricity was increasingly removed from the State (regional) level and transferred to new scale forms, with (internationally-owned) firms being the new locus of power. New spaces for the circulation of capital were opened up through the process of privatisation and opportunities for regulating production and consumption were downscaled through the rhetoric of "light handed regulation".

Victoria was able to enact such a radical transformation in the practice of electricity supply because of the confluence of local, national and international processes. The blueprint for reform of the electricity industry from the Commonwealth Industry Commission gave reformist actors within State governments and the electricity industry much needed support for market-oriented restructuring.

Key actors such as Dr Alan Moran wove their way through these processes, moving from the Commonwealth level, to the trans-Tasman think tank that heavily influenced Victorian conservative thinking whilst in opposition and then into a senior position within the Victorian government that made decisions on the regulatory framework of the market and levels of government support for energy efficiency. The Treasurer Alan Stockdale was heavily influenced by privatisation developments in the UK and relied on an army of international consultants to make the case for industry restructuring.

Conclusion

The case study shows how the transition to more sustainable demand management practices through the process of market liberalisation and regulatory restructuring of the Victorian electricity system was a highly contested, multi-scalar process that is not easily explained by relying solely on the MLP framework. The findings in the paper cut across the more linear view of innovation as simply interactions between niche, regime and landscape. Far from being nested hierarchical interactions from the local to the national, there were interscalar back and forth interactions that influenced the nature and pace of the transition.

In order for the MLP framework to be able to better explain sustainability outcomes through processes of market liberalisation a more nuanced account of the reshaping of scale, networks and territorial relations is required. The period of transition to a liberalised market was characterised by opportunities for shaping debates on the future operation of the market. The failure to "lock in" a more sustainable approach to demand management in this early phase was a result of spatially differentiated approaches at the national and State level and a struggle for control of the liberalisation process.

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THE LOGIC OF SOCIETAL INNOVATION

How Socio-Technical Solutions to Societal Needs Become Institutionalised

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Abstract

Is there a logic to the uptake of societal innovations? If societal innovations are novel ways to meet societal needs, such as certain forms of health care, transport or simply drinking water supply, is there a system to how they emerge? Can a system be identified in how social innovations build upon present infrastructures and institutions? The article presents the first steps towards a framework to systematically describe societal innovation. The framework distinguishes generations and stages of institutionalisation to unravel processes of societal innovation into the sequential uptake of societal and socio-technical solutions to meet societal needs. The overall logic of these sequences is explained and presented as *propositions*, illustrated with examples from Melbourne's (Australia) stormwater system. These propositions connect the development (growth, decline or otherwise change) of societal needs to the staged emergence of new socio-technical solutions to meet those needs, sometimes leading to socio-technical lock-in and other times giving rise to transitions. While an urban water illustration is presented, the framework is more general, and the formulation of the propositions and overall logic is such that they can be applied to any societal system, even non infrastructure-focussed sectors. The article shows that, combining ideas from institutional theory with a transitions perspective, a logic to the uptake of societal innovations can be identified which provides a more detailed and systematic understanding of societal innovation.

Introduction

Transitions studies have, as they should, progressively been producing more sophisticated explanations of transition dynamics: from the early multi-level perspective (Rip and Kemp, 1998) and the s-curve representations in the multi-phase concept (Rotmans et al., 2001), through a typology of pathways (Geels and Schot, 2007), to a multi-pattern approach (de Haan and Rotmans, 2011) and motors of innovation (Suurs, 2009). This progression seems to suggest an approach from the outside in, with the explanations acquiring more detail as transitions are unravelled further into paths and patterns.

This article proposes a basis for such explanations, from the inside out. That is, to describe the basic processes that underlie transitions, from the lowest level up. What those lowest-level processes are is of course a bit of a Russian doll kind of problem, and what level is that anyway: Technological artefacts? Individuals? Psychology? Elementary particle physics? Given that societal[1] systems and transitions can be considered on many scales – for example from a technological substitution case on a neighbourhood scale (e.g. solar powered suburb) to a complete reorientation of a sector on an international scale (e.g. post World War II agricultural intensification in Europe) – one needs to look at processes that are at play across the scales.

One way to address this predicament, is to look at transitions as processes of *societal innovation* in the way Rotmans (2005) did. Societal innovation can be considered at various levels, with the highest level the overall transition itself and at the lower levels the societal innovations that build up to it. This article presents a theoretical framework for societal innovation that allows researchers to unravel the logic of societal innovation.

Societal innovation would obviously have things in common with other forms of innovation and similarly much revolves around the issue of uptake and its drivers. The view presented here is that the main driver for the emergence of societal innovation is the presence of expressed societal needs (de Haan et al., forthcoming in 2013). Needs are more often considered central in the adoption of innovation, for example in Kemp's (1994) discussion of technological innovation in the context of transitions, needs (market needs, technological needs) play a central role. Needs are of course not the only determinant for an innovation to be taken up, context constraints and competition play important roles as well and therefore they will also be discussed here.

[1] For reasons of brevity, from here on the term societal system will be understood to denote either a socio-technical or societal system, i.e. the class of socio-technical systems is considered to be contained in the larger class of societal systems.

To exploit the parallels between societal and technological innovation a bit more, it seems necessary to identify more clearly what is ‘taken up’, what it is that actually changes in a societal transition, what the unit of analysis should be. Obviously, a socio-technical or societal system is what changes, but what of it changes? Allusions are made to ‘structural aspects’ (Rotmans et al., 2001), for example, or the ‘sociotechnical configuration’ (Geels, 2002), to bring in two different, though not necessarily differing, views. But, structures and configurations of what? A barrage of ways appears around to describe these: from stocks and flows of varying sorts in the former reference, to symbolic meanings, infrastructures, rules and policies in the latter. Is there, then, no universal unit of description to be found?

Oftentimes, what would have changed following a transition is described functionally, for example by suggesting a definition of a transition as a shift “from one *mode of operation* to another” (Rotmans and Dowlatabadi, 1998, original quotes replaced by italics). Or, referring to “the way societal functions (…) are fulfilled” (Geels, 2002). This is very appropriate, as the only sensible way to look at societal or socio-technical systems is in reference to their function in society, the needs they fulfil. It also is a key to finding what could serve as the ‘artefact’ of societal innovation. The article proposes the introduction of societal solutions as the way societal needs are fulfilled. Societal solutions, in this view are composed of not only the means of meeting the need, like infrastructures or organisations, but also of how they are used and fit in society, by which is meant notions like the norms, rules and perceptions that accompany these means of meeting. These latter notions will be elaborated as the *institutions* of the solution, whereas the former part will be described as the *facility* of the solution, which is the means of delivering upon the societal needs.

Looking at societal solutions as combinations of institutions and facilities, allows an interpretation of societal innovation as a process of institutionalisation. This article proposes to see institutionalisation as a *staged* process, where different kinds of institutions appear sequentially. Similarly, facilities, or infrastructures in the illustration of this article, are considered to develop in *generations* that build upon each others. In this, way the institutionalisation of a certain *lineage* of societal solution can be unravelled into several stages and generations.

Facets: Socio-Technical Solutions to Meet Societal Needs

Having established that societal innovations emerge as solutions to meet societal needs, it is time to investigate what these solutions would entail. In Kemp’s (1994) discussion of innovation in response to needs, technological or market needs in his text, the solutions these innovations represent are technological. There is no doubt that technology provides solutions to societal needs as, for example, the relation between public health and sanitation illustrates. There is also no doubt that there are solutions to societal needs that are non-technical. In many cases the societal need is met through a facility delivering some kind of service, think of knowledge needs and the educational facilities that have emerged over time to meet them. In fact one could posit that there are several kinds of facilities, i.e. technical and social structures with the function of meeting a societal need. Examples are – and this is not meant to be the definitive or exhaustive list – infrastructure, organisations, arrangements (e.g. retirement or subsidies) and practices. The only kind of facilities explored in this article, however, will be infrastructures, that is socio-technical solutions to meet societal needs.

Facilities, like infrastructures, are merely the tools when it comes to meeting societal needs and like with tools, the way they're used is as relevant as what tools are used. The way infrastructures and other facilities function in society, is determined by the institutions around them, ranging from knowledge to norms to rules and regulation. This idea is akin to how Rip and Kemp (1998) talk about regimes – which are constellations of solutions to meet societal needs (de Haan and Rotmans, 2011) – as "…the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems – all of them embedded in institutions and infrastructures". This article defines a societal solution as facilities, such as infrastructures, organisations, arrangements or practices, in combination with institutions that together have a societal function, that meet societal needs.

Institutions in this article are understood in the sense of Scott (2001) and applied in a way that was described earlier in (de Haan et al., 2013 in press, de Haan et al., forthcoming in 2013, Ferguson et al., submitted 2013). Scott distinguishes three institutional pillars: cultural-cognitive (e.g. common beliefs, shared logics), normative (e.g. certification, accreditation) and regulative (e.g. rules, laws). The interpretation here is that an infrastructure, or other facility, is considered institutionalised when all institutional pillars are fully developed.

To give a bit of a prelude to the full logic of societal innovation: one can readily see that for some infrastructure that could be part of a solution to certain societal needs, a trajectory of institutionalisation is followed. For example, looking at Geels' (2006) description of the hygienic transition in the Netherlands, one can identify stages[2] of institutionalisation that correspond to the abovementioned pillars. The case describes how cities in the Netherlands implemented sewer systems from the late 19th to the early 20th century. These sewer systems replaced several decentralised

[2] Geels also describes the institutions involved in this transition using Scott's pillars, but does not talk about a sequence and actually sees the emergence of institutions as *preceding* the implementation of the infrastructure, whereas in this article the emergence of institutions necessarily is *a part* of the implementation.

practices of human waste management, but can essentially be seen as the institutionalisation of sewer system infrastructures. By the time Dutch cities started implementing sewers, the technology was already known and tested in many cities around the world. First a number of cultural-cognitive changes could be observed about perceptions and knowledge of hygiene, the well being of the working class etc. Then, normative institutions could be seen to develop, the notion that sewer systems are a preferred solution and negotiations about the design and the level and kinds of services to be delivered. Finally, regulative institutions emerged in the form of the approval and actual implementation and putting in to use of the infrastructure[3]. Please note that in this case the sequence seems to suggest that cultural-cognitive institutions precede normative ones that precede regulative ones. This is, however, not necessarily the case in general. This point will be touched upon again later.

The idea of stages or trajectories of development is even more straightforward when thinking of infrastructures or technologies. Scholars like Dosi[4] (1982), speak of technological trajectories along which technological innovations build upon each other. A straightforward example would be treatment facilities for stormwater runoff, where subsequent levels of treatment are met with new generations of infrastructure that build upon the previous, going from primary treatment which includes simply removing litter with gross pollutant traps all the way through to tertiary treatment and treatment to drinking water standards.

Both for technological generations following each other as for how institutionalisation progresses through its three pillars holds that either the solutions fulfil the societal needs better or more fully, or that more needs are being met. A better system of knowledge, norms and regulation is likely to improve the performance of a stormwater drainage network and one sees that down the technological generations not only needs for flood protection and environmental protection, but also potable water can be met. In general any solution could meet several societal needs, and any one societal need could potentially be met by several solutions.

Illustration: Urban Water Drainage Solutions

The theoretical framework described in this article was developed and applied in a modelling project[5] and accompanying case study. The case concerned societal innovation in the context of stormwater

[3] This analysis differs slightly from Geels's as he also refers to institutions that have influenced the transitions, e.g. certain health acts, but that cannot be interpreted themselves as part of the institutions around the sewer system solution.

[4] The idea is described in varying forms by others as well.

[5] DAnCE4Water, see also the acknowledgements.

management in the Melbourne (Australia) region. The study spans roughly the period from 1960-2012. The case is used here only to provide an example of technological generations and institutional elements of solutions to societal needs. The context of the case can, however, be found in (Brown and Clarke, 2007) and analyses are provided in (Brown et al., in press 2013, Ferguson et al., 2013).

For this case, seven needs were identified as important for the dynamics of the societal innovation:

- Potable Water (drinking water, supply safety)
- Public Health (waterways and water intense urban features pose no health risk)
- Non-potable Water (water supply for irrigation, industry, &c)
- Property Protection (flood protection mostly)
- Ecological Health (waterway health, ecosystem conservation)
- Amenity (urban aesthetics, human thermal comfort)
- Intergenerational Equity (resource preservation, ecological restoration)

This is a subset of the more complete, and well underpinned system of needs developed in (de Haan et al., forthcoming in 2013), where also a hierarchy is identified, which for example means that solutions to some ‘existence’ needs are typically prioritised over others.

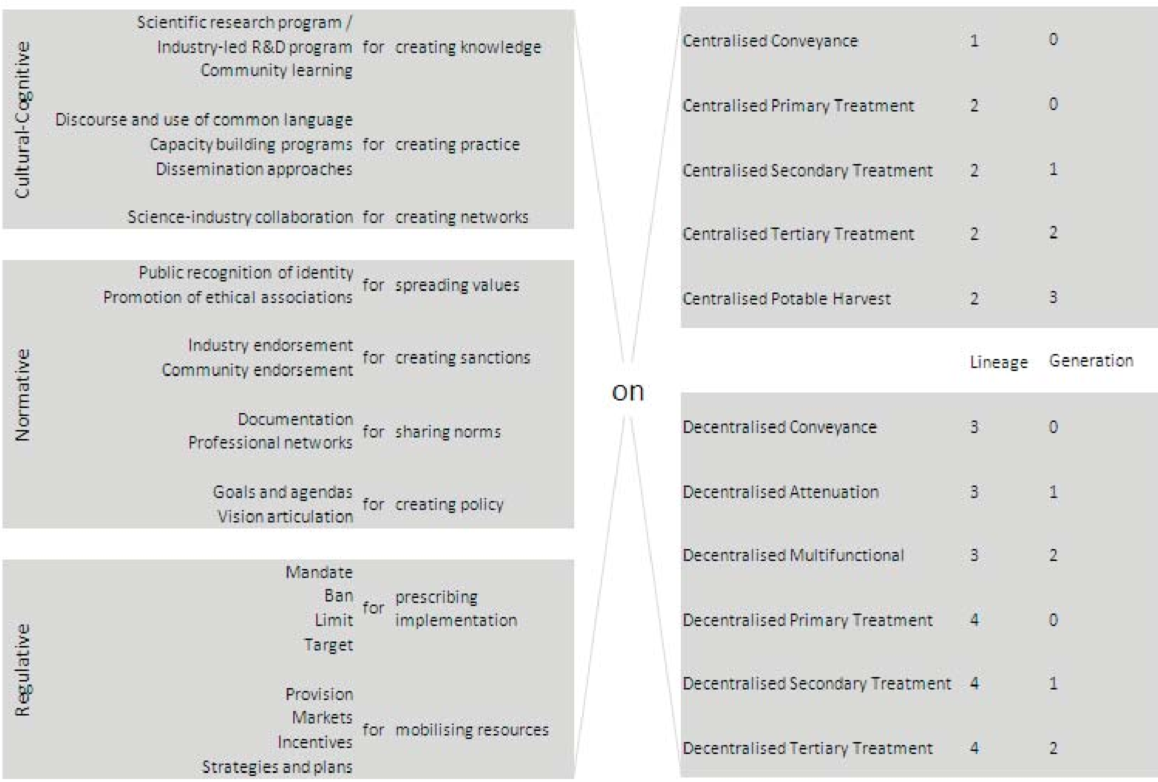

Figure 1. Solutions to societal needs unravelled into their institutional and infrastructural parts.

The urban water servicing solutions to meet the seven needs can be read from Figure 1 in the most literal sense. The left-hand side of the table lists the suite of potential institutional elements of the possible solutions and the right hand side each facility – in this case infrastructures – those institutions could apply to[6]. For example 'Documentation for sharing norms on Centralised Potable Harvest' would be a part of the institutionalisation of stormwater harvesting for drinking water purposes as a solution to meet the need for potable water. Similarly, a 'Target for prescribing implementation on Decentralised Secondary Treatment' would be a part of the institutionalisation of stormwater quality infrastructure meeting needs like amenity and ecological health in addition to property protection.

Illustration from the case study:

At the beginning of the case study period, the socio-technical solution for managing stormwater was focused on the protection of properties from floodwaters. This was achieved through a large-scale piped drainage system that rapidly conveyed stormwater to downstream rivers and creeks. Institutions that accompany this piped drainage regime include technical knowledge about catchment hydrology and pipeline hydraulics, normative networks of drainage engineers and codified standards for flood protection, and regulative arrangements for resourcing drainage infrastructure maintenance.
From the 1960s to 1980s, the community became increasingly concerned with the poor health of these urban waterways and in the 1990s, a new cognitive understanding of the links between stormwater pollution and its impacts on waterway health and urban amenity emerged. It was now recognised that the traditional approach to stormwater drainage was inadequate for addressing pollution impacts and improving the health of waterways. This new insight stimulated scientific research and development of stormwater quality treatment technologies (such as constructed wetlands), leading to the formation of a new socio-technical niche between 1996 and 1999.

As awareness of stormwater quality issues and potential solutions increased, normative science-policy networks began to form and key organisational actors acknowledged their shared responsibilities for stormwater quality treatment. Between 2000 and 2003, focus was on mainstreaming these new cognitive understandings through design guidelines, decision-support computer software and capacity building programs. The normative networks around stormwater

[6] The infrastructural parts of the solutions were identified in collaboration with Monash' Department of Civil Engineering and the institutional parts were identified by scholars from the School of Geography and Environmental Science.

quality treatment continued to expand and became more formalised, as different types and a greater number of actors got involved.

From 2004 to 2012, state government officials engaged with the question of stormwater quality treatment and introduced regulative mechanisms to set targets and incentives for the implementation of new technologies. Cognitive development for the next generation of stormwater quality treatment infrastructure (in the form of advanced biofiltration technologies) was undertaken, which raised the new potential for treated stormwater to be harvested as a water resource. Capacity building around the design, implementation and maintenance of stormwater quality treatment infrastructure continued. Water sector discussions shifted to the need to mandate minimum levels of stormwater quality treatment so that the low-performing organisational actors were forced to deliver best stormwater management practices.

As mentioned earlier in this article, societal innovation is considered to be driven by needs that are expressed in society and therefore the development of socio-technical systems is considered to go hand in hand with evolution of societal needs, as for instance explored in (de Haan et al., 2013 in press). But this is of course not the entire story, since otherwise socio-technical systems would meet societal needs better and better until all needs are fulfilled. The process of institutionalisation, regardless of how much a need is expressed, can be impeded by many context factors, constraints like scarcity of resources, unsuitable geographic conditions, unfavourable consumer preferences or political climate, there might be financial constraints and so on. Both the expression of societal needs and the presence of constraints are landscape factors, context conditions.

Another matter is competition, the expression of certain societal needs may give rise to different societal solutions, different lineages that may institutionalise to varying degrees, either coexisting, forming different stable niches or competing over resources or adoption and leading to the establishment of one of them as a – possibly new – regime. Alas, the story of transitions. For example, in the Melbourne case study, the emerging niche around stormwater quality treatment presented distinct competition for the existing piped drainage regime, which does not address the need for ecological health. The existence of competing solutions can itself be a pressure for transitional change, as identified in (de Haan and Rotmans, 2011), but this will not be discussed here.

Unravelling the Logic

The logic of generations of infrastructural facilities seems straightforward, once an infrastructure has been found to meet a need, a next generation may emerge, building upon it, to meet the same and potentially other needs. The institutional logic is less self-evident. Although the review of Geels' (2006) case suggested a sequence of cultural-cognitive first, then normative and finally regulative institutions, this by no means needs to be universal. For any given facility, infrastructure or otherwise, several different sequences of stages of institutional pillars in principle is possible. For example the adoption of infrastructures for harvesting of stormwater for potable reuse could be regulated well before proper norms have emerged. However it does seem logical to assume that the cultural-cognitive pillar needs at least some development before the normative or regulative ones can build upon it. In other words, some shared knowledge, discourse and such needs to be present before norms, policies and rules can be formulated. Summarising this paragraph in propositions:

- The emergence of facilities of a certain generation depends on the presence of facilities of the previous generation within the same lineage. Except, of course, facilities that are of a zeroeth generation.
- For any facility of a certain generation, the cultural-cognitive institutions emerge first.
- For any facility of a certain generation, the normative and regulative institutions can emerge independently of each other, either simultaneously, or either one after the other.

Does it matter how well a solution is institutionalised for a facility of a subsequent generation to emerge? Do all institutional pillars need to be present before the institutionalisation of the next generation can begin? It seems possible for certain generations of an infrastructure to never be actually implemented on the ground whilst a subsequent generation makes it to widespread adoption. For example when certain technology reaches maturation in a laboratory situation but really only the offspring thereof gets adopted. By this thought experiment one can hypothesise that the presence of the cultural-cognitive institutions is required for the emergence of subsequent generations, though normative and regulative institutions can emerge separately. That is to say, the legislation or norms and values of generation n can emerge without reference to the legislation or norms and values of generation $n-1$, however not without the knowledge and other cultural-cognitive aspects of that previous generation. As a proposition:

- For facilities of a certain generation to emerge, only the presence of cultural-cognitive institutions is a necessary requirement.

Although more speculative, it is interesting to continue these lines of thought to the matter of *deinstitutionalisation*. That is, what is the equivalent of the above logic in the case of a societal solution becoming obsolete, when the need for it disappears or diminishes to a large degree? By symmetry it can be concluded that in the case of phasing out a societal solution, the cultural-cognitive institutions will fade last: if normative and regulative institutions depend on them for their emergence they apparently have some supporting quality that makes it likely that they will only fade after the normative and regulative institutions have. Also by symmetry there seems to be no reason to assume a priori that either the normative or regulative institutions fade first, if they can emerge independently, they can fade independently. Across the generations, the proposition that the presence of cultural-cognitive institutions is a necessary requirement for the emergence of a new generation seems to presuppose that the normative and regulative institutions of a facility of generation *n-1* can fade whilst cultural-cognitive institutions will remain in place as long as those of generation *n* are. In propositions:

- In the phasing out of facilities, cultural-cognitive institutions are the last to fade, after normative and regulative institutions.
- In the phasing out of facilities, normative and regulative institutions can fade independently of each other, either simultaneously, or either one after the other.
- In the phasing out of a facility of a certain generation, the normative and regulative institutions can fade whilst a facility of a subsequent generation is still institutionalised.
- In the phasing out of a facility of a certain generation, the cultural-cognitive institutions remain as long as there are cultural-cognitive institutions of a subsequent generation.

Conclusion

This article presented the first steps towards a framework to systematically describe societal innovation. The framework is meant to be an extension of the current theoretical perspectives of transitions studies. The concept of societal solution was introduced to provide a unit of analysis to understand societal innovation as a process of staged institutionalisation of means to meet societal needs. Societal solutions are understood to consist of facilities (e.g. infrastructures or organisations) and institutions. On the facility side, *generations* are distinguished among the solutions and their institutionalisation is suggested to be a *staged* process. A set of societal solutions for urban stormwater management in Melbourne, Australia, has been presented as an illustration.

The logic of societal innovation has been presented in the form of propositions to reflect the tentative nature of this framework, and to assist in its further development through case study and modelling research. More case-study work is necessary to expand the framework towards including other kinds of facilities than the infrastructural ones used in the illustration in this article but also to test and possibly improve, or add to, the propositions. Apart from case study analysis modelling work would be instrumental in strengthening of the framework by adding rigour and taking steps towards quantification.

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Renewable energy communities:

exploring the transition potential of internally oriented niches

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Abstract

The Multi-Level Perspective (MLP) provides a framework for the analysis of long-term socio-technical transitions. However, according to some of its critics MLP simplifies the complexity of the regime and niches and downplays the importance of social innovations in sustainability transition. The aim of the article is to address these issues by introducing a different interpretation of the micro and meso-levels and by arguing that transition can also partly occur without the transformation of the entire socio-technical system. Furthermore, it makes a distinction between internally and externally oriented niches regarding their orientation and application focus. Through the example of renewable energy communities in the Netherlands we demonstrate that social innovations developing together with technical artifacts in niches are also very important drivers of this change and the transition potential of a niche depends on its capability to establish a great number of strong links with various social groups in the regime. The method we used is a comparative case study analysis complemented by systematic literature and documentary review about the state of Dutch renewable energy communities. Our results show that these communities are transforming niches. They have the capacity for scaling up and their embedding into the regime has already started.

1. Introduction

Transition scholars all agree that the current way of energy production is not sustainable in the long run and without a radical change favoring renewable energy, the negative impacts of climate change and depleting fossil resources cannot be avoided. The literature is less clear about how this future system would look like and how transition can be realized. In order to gain a better understanding about the so-called socio-technical (ST) system and the way how innovations develop and take over the dominance of incumbent technologies, several theories were developed, such as strategic niche management, transition management or the multi-level perspective (MLP). While the first two theories have many features in common and intend to steer a long-term societal change by taking a governance approach (Kemp et al., 1998), this latter aims to provide a framework for the analysis of historical transitions (Geels, 2004).

In this article we will deal with this third transition theory, which provides an analytical concept for studying transition to sustainability. According to its critics, however, MLP too much simplifies this complex process and disregards specific elements that also play an important role in the transformation of the regime (Berkhout et al., 2004; Genus and Coles, 2008; Markard and Truffer, 2008, Safarzyńska et al., 2012). Therefore, we will further elaborate the theory by analyzing the complexity of the regime and studying the nature of niches. Furthermore, we will also pay more attention to the role of civil society and social innovations in the transition, since they can be at least as important drivers of this change as technical innovations. To do so, we take the examples of renewable energy communities. That provides us a good opportunity to examine niches developing technical and social innovations at the same time. These communities are innovative groups that in contrast to mainstream society are more self-conscious and able to stand up for their needs and realize joint investments.

The question is to what extent renewable energy communities, as socio-technical niches, have the potential to scale up and contribute to energy transition. To answer this question we use the results of comparative case study research, which focuses on four different cases in the Netherlands. We have conducted interviews and surveys, as well as analyzed documents, including legislation and policies. The paper provides an overview of the state of renewable energy communities in the Netherlands, both from the demand side and the supply side perspectives, examining all the services, as well as legislation and policies in force that are related to them. In addition, through our cases we illustrate the diversity of communities regarding their locations, size, technologies and motivations.

This paper shows that there is already an increasing number of different local investor groups in the Netherlands, around which a complete infrastructure is building up. It argues that renewable energy communities are not only a few homogenous groups sharing the same values and needs, but there are more and more different communities investing in renewables locally for diverse reasons. Furthermore, technical, legal, financial infrastructure and other services are developing around them. As a result, these communities could survive the valley of death and their embedding into the regime has already started. In case they receive adequate governmental support, they would be able to spread in the regime more easily.

This paper contributes to transition studies, by focusing on elements that are rarely taken into account, namely: demand side factors as well as the role of civil society in the transition. Furthermore, it aims at elaborating the notion of the regime and of the niches, in order to provide for a comprehensive answer on how social innovations evolve and transform the incumbent energy system. Thus, besides studying the state of renewable energy initiatives in the Netherlands from the transition perspective, we also contribute to a better understanding of sustainability transitions.

2. Multi-level perspective

The multi-level perspective (MLP) was developed to establish a framework for the analysis of socio-technical transitions and to gain a better understanding on how innovations emerge and shift the incumbent regime to sustainability. MLP distinguishes three interdependent system levels through which transition occurs: the niche, the regime and the landscape level. However, there are ambiguities in the definition of these levels, especially in case of the socio-technical regime.

Geels (2002), based on the concept of the technological regime defined by Rip and Kemp (1998), introduces the term socio-technical regime, which is a semi-coherent set of rules put into practice by different social groups and located between the landscape and niche levels. Within the socio-technical regime several sub-regimes can be found (science regime, policy regime, socio-cultural regime and the users, markets and distribution networks regime), which represent different social groups and which are aligned to each other by rules. The ST regime, however, does not include the entirety of these regimes; it is rather a grammar or rule set among them (Geels, 2004). In contrast, Safarzyńska et al. (2012) define the regime as a combination of tangible and intangible elements that encompasses besides rules also material artifacts. Markard and Truffer (2008) note that the definition of the regime largely depends on the research question, since it comprises different levels of aggregation of perspectives. Transition scholars agree on that the regime is characterized by path dependence and lock-in (Unruh, 2000), which reinforce the dominance of the incumbent actors, technologies, rules, institutions, practices and infrastructure, thereby stabilizing it in all dimensions. Only incremental innovations are favored by the regime leading to particular trajectories, which are resistant to change. Therefore, transition occurs when a radical innovation can make a shift from one regime to another regime (Geels, 2011).

The macro or landscape level represents external processes and factors that influence the regime, and it is beyond the control of the meso-level's actors. Changes at the landscape level either reinforce the incumbent trajectories or put pressure on the regime, which process destabilizes the regime's structure and creates 'windows of opportunities', where radical innovations can break through (Geels, 2002).

Niches form the micro-level of the socio-technical system providing protected spaces for innovations. Geels (2004) defines the socio-technical niche as the locus for radical innovations. They are located outside of the regime and create special conditions for new technologies that would not be able to succeed within market circumstances due to their low technical performance. Thus, niche actors develop radical innovations with the intention that they will be used in the regime or even that they become the dominant technologies in the regime (Geels, 2011). In contrast to the regime, which is considered as a system of different dimensions, niches are defined by scholars as incubator rooms or locations, where innovations emerge isolated from market pressures and which also provide space for the formation of new socio-technical practices, actor networks and rules (Markard and Truffer, 2008). It is important to note here that the literature applies the word ‘innovation’ in an inconsistent way, since it is used either as a synonym for new technologies, or, in other cases, it also refers to the combination of new rules, practices and networks coevolving with the technical artifacts, including thus technological and social innovations.

The three socio-technical levels are forming a nested hierarchy and their co-evolution is necessary for transition. Since the regime is in favor of only incremental changes, which reinforce the dominance of current actors and technologies, only radical changes can induce transition (Elzen, Wieczorek, 2005). When mismatches occur at landscape level or within the regime they create ‘windows of opportunities', where radical innovations can break through and enter the meso-level of the ST system. Geels describes the process further:

“It then enters competition with the existing system, and may eventually replace it. This will be accompanied by wider changes (e.g. policies, infrastructures, user practices).” (Geels, 2004, p. 915).

Accordingly, innovations mean new radical technologies here that emerge in niches. After a time, they are able to leave these protected spaces, take over the place of the incumbent ones and together with wider changes form a new regime (Geels, 2004). This process takes place step by step, when changes in one element of the regime (e.g. the emergence of a new technology) induce changes in other elements, thereby reconfiguring the entire system. Consequently, new regimes grow out from old ones (Van den Ende and Kemp, 1999).

The MLP theory was criticized by several scholars (Markard and Truffer, 2008; Vasileiadou and Safarzynska, 2010; Smith et al., 2010; Kern, 2011) for, among others, its exclusive technology focus neglecting social and cultural aspects in transition (Geels, 2005) and referring to innovations as technical artifacts without considering other options, such as social or grassroots innovations (Seyfang et al., 2010). Thus MLP underplays the effects of social and cultural aspects co-evolving with technologies on transition (Genus and Coles, 2008). Secondly, according to the critics, MLP downplays the role of agency in transition (Hoffman, 2013). For example, it is taken for granted that technologies that can induce regime shift are per se the most efficient options from the techno-economic point of view and power relations have no influence on that (Smith et al., 2005). Thirdly, there is a confusion about the starting and ending points of transition. Interpretations of MLP on different cases have shown a large scale variety in this respect, and only historical analysis is able to identify which set of events can be defined as the beginning and which are the end of transition. Moreover, this question also very much depends on the decision-making of the analyst (Genus and Coles, 2008).

These criticisms demonstrate that transition is a very complex process and the framework of MLP has to be further elaborated for a better understanding of changes in the socio-technical system. Based on Geels' definition of MLP and considering the above mentioned criticisms we analyze and elaborate the theory, by concentrating on niches and the structure of the ST regime. Further specifying our research question, we are interested in the nature of niches, their potential for scaling up and the way in which they induce transition. Therefore, first we introduce a different interpretation of the regime and niches by arguing that they are complex systems, combinations of interlinked elements. Second, we make a distinction between niches according to their orientation and application focus. Finally, we plead that transition can occur partly in the regime by building up links between the niche and certain social groups of sub-regimes. In the empirical section all the arguments presented here are illustrated by examples taken from renewable energy communities in the Netherlands.

2.1 The fragmentation of the ST regime

As a first step we discuss the construction of the socio-technical regime and niches. Geels (2002) defines the ST regime as a structure of different sub-regimes, which represent different social groups aligned to each other by rules. However, according to Geels, they form one system, which is, during transition, replaced by a new one. In contrast, in this paper we will utilize the conceptual possibility to see the regime and its sub-regimes as even more fragmented representing different social-groups with divergent interests and intentions at the same time.

Thus the regime can be seen to encompass the variety of products, their demand groups and all the other dimensions related to them, even though due to path-dependence and lock-in certain technologies are marginalized. There are different demand-side groups driven by diverse forces and if a product cannot prevail in one market segment, it is not self evident that it cannot find its sufficient demand in other groups. Taking the Dutch energy system as an example, we can see that even though it is very much fossil based and characterized by path dependence and carbon lock-in, which is also proven by the fact that the renewable energy share is still 4.2%, one of the lowest in Europe (ECN, 2011), it cannot be still considered as a unitary whole. There are different forces present, which partly reinforce the dominance of the incumbent technologies. Although the energy production is mainly centralized and based on large-scale fossil power plants, keeping renewables still at the periphery of the market, the target group that this energy is supplied for is divided in a more balanced way.

On the one hand, one can find major companies and factories interested in large-scale and cheap electricity supply. Aiming for profit maximization, they favor mainly cheap fossil fuel, which is accessible in large quantity, thereby ensuring low production costs and smooth operation. The second big group of consumers is the one of private end-users aiming also for low prices; however, in their case other, even contradictory considerations might be present influencing their energy preference. There are more and more people led by environmental motivations who choose either suppliers offering ‘green' energy or also invest in renewables and partly cover their own needs, even if it is not always the most cost efficient solution. Consequently, we can make a distinction between these two consumer groups not just regarding the quantity of their energy need, but also according to their preferences.

Thus, each demand side group has probably not only one, but at least two or more types of preferences, and at the same time a given group can be interested in different, even opposite solutions. Accordingly, some private end-users can be interested in cheap fossil energy, but others led by environmental considerations would prefer renewables or at least the mixture of ‘dirty' and ‘clean' energy. Although it is not clear what the proportion of this division is and to what extent environmental values are present in the consumption decision, we can already presume that the coexistence of different technological regimes is possible. These might be targeting different demand side groups/user regimes and still overlap at certain points.

The work of Alkemade et al. (2009) about assessing possible transition pathways based on the rugged fitness landscape underlies our conception of the regime as an interdependent complex system. They also argue that it is built up from several interdependent subsystems combined in different ways, which provide the fitness of the regime and all possible combinations of subsystems form the design space of the regime. The number of designs, even in case of a few subsystems, is large and transition occurs through the combination of them.

Figure 1. represents the fragmentation of the ST regime, distinguishing between not only different types of sub-regimes, but also within one sub-regime (group of end-users, group of technologies). The arrows show the bonds between them, dark arrows indicate strong bonds and the lighter arrows weak bonds. We can see that to some extent all the regime groups overlap with each other, but some bonds between certain demand side groups and certain technologies are stronger depending on the specific needs of the group, which the given technology can meet the best. The same fragmentation and connection network can be observed concerning the other sub-regimes (policy, science, socio-cultural sub-regimes).

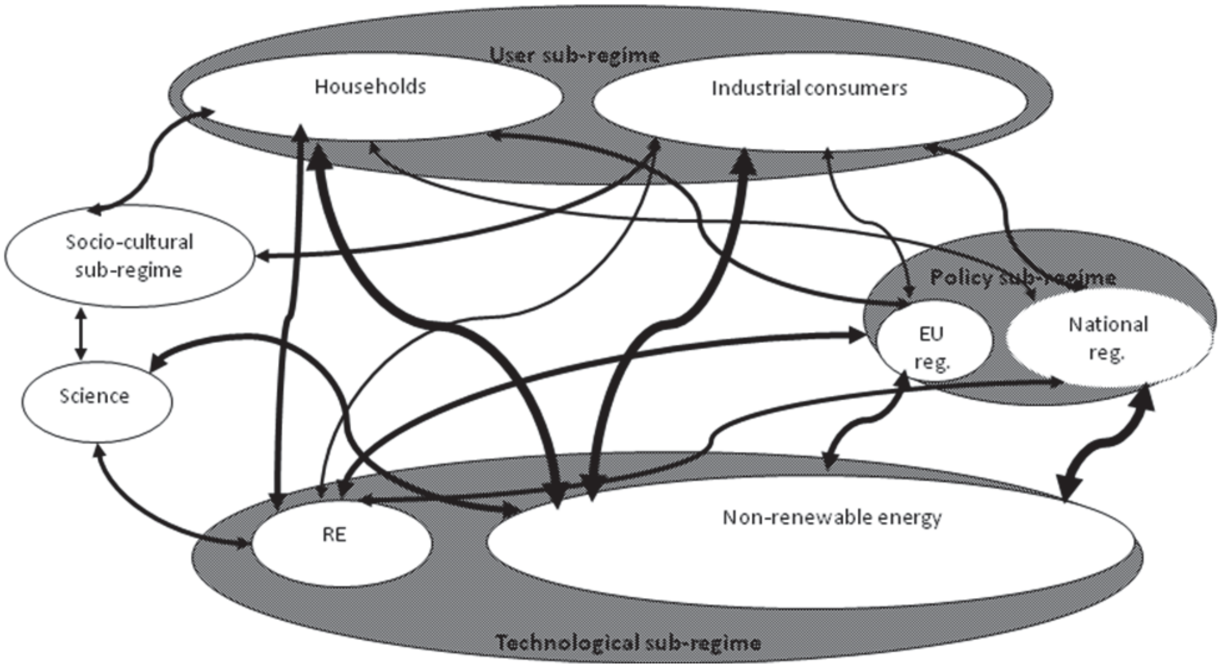

Figure 1. The fragmentation of the socio-technical regime

2.2 Niches as complex systems

Turning our focus to niches, we also conceive of niches, similarly to the regime, as complex systems, rather than only protected spaces where innovations develop. If we take a look at Geels's (2004) definition of niches, we see that it is vague about what happens to all the dimensions (social networks, rules, socio-technical practices) that develop in niches together with the technology. Actors create networks, infrastructures, establish new practices and rules, which are different from market conditions, thereby creating space for the new technology to develop. Markard and Truffer (2008) also claim that it is a protected space, which is similar to the regime in its structure; although the level of aggregation and stability are much lower in this case. Yet, it is less explained what happens to all these other dimensions when the technology leaves the protected space and enters the regime. Do they disappear?

This question implies another interpretation of niches: they might be also considered as not just protected spaces, but as systems that are still forming, with lower stability and higher complexity than the regime, from where not only technologies break through, but which establish links to incumbent social groups. Niches are thus considered able to shift regime elements by the network they create and form. The ST system itself can be interpreted as a combination of different sub-regimes (policy, technological, socio-cultural, etc.) that coexist, and it is aligned by rules followed by different social groups (Geels, 2004).

Consequently, niches that represent the rule set of new social groups and that achieve a certain maturity level can be able to enter the ST regime and create links to the other sub-regimes and shift them. This process would then trigger changes in the entire ST system. However, it would not necessarily lead to its complete transformation.

In other words: in niches certain social groups can develop innovations. It is important to note here, that innovations are not only technologies, but that they can also be social innovations – the development of new strategies and practices that strengthen civil society and meet social goals (Mulgan et al., 2007). In contrast to the mainstream or market society these actors have a special interest in the innovation and that is why they are even willing to invest money, time or energy and take also the risk of failure. Since the innovation might not survive in market circumstances, they have to create the needed physical and social infrastructure in order to improve it to the level that it can stand market competition. Thereby a whole new system develops with all the system elements, similarly to the ST regime. Niche actors form the user and distributor network, which is built up around the innovations. The practices they use and the patterns they establish provide the socio cultural elements of the new system. In case the niche reaches a certain size with a large number of actors or it generates special features that cannot be regulated by the incumbent rules, or due to the strong advocacy power of the niche actors, the government can be expected to establish new policies specifically targeting them.

2.3 Internally and externally oriented niches

Furthermore, the MLP is less specific about who the actors are in niches and what their role is in the development of radical technologies. The theory does not specify what niche actors aim for and what the development of a technological innovation precisely means, e.g. just the improvement or also the invention. The next question is whether niche actors develop technical artifacts for later regime use only or for their own purposes. There might be social groups that differ from mainstream society and have special needs that can be met only by these new technologies. In this case it is also possible that niche actors do not have the primary aim of ‘sending’ the technology into the regime.

As such, niches can differ regarding their actors and their purposes. Niches created by market actors that want to invent and develop new technologies for later regime use are different from social groups having specific needs that cannot be satisfied by incumbent regime products. This latter group’s (such as grassroots communities or the army) purpose with the niche creation is to nurture innovations that are able to meet their special needs, and it is possible that they only aim at the internal use of the innovation.

Consequently, distinction can be made according to the orientation focus of niches, thereby defining *externally* and *internally oriented niches*. Furthermore, we can also differentiate them regarding their application focus. The *externally oriented niches* are organized around a technological innovation and the other components of the niche are subordinated to it. Contrarily, in the *internally oriented niches* the emphasis is not on the technology itself. Technologies serve more like a tool that actors use for their special purposes. In this case social innovations can play as important role as the new technologies.

Transition scholars have so far neglected demand side factors, social practices and the role of civil society in the transition processes, as much as they underplayed the importance of social innovations in transition (Hielscher et al., 2011). In addition, grassroots initiatives are also disregarded as potential niches, in which both technological and social innovations are developed. The basic idea behind grassroots initiatives is that instead of remaining powerless as end-users who want to act or change their dependent and vulnerable situation individually, but are stuck within the current regime, they can jointly stand up for their interests, form a niche and create conditions that are suitable for their needs and that they can control themselves (Seyfang and Smith, 2006). Seyfang and Smith (2007) define grassroots initiatives as "innovative networks of activists and organizations that lead bottom up solutions for sustainable development; solutions that respond to the local situation and the interests and values of the communities involved." They also claim that grassroots initiatives "… involve committed activists who experiment with social innovations as well as using greener technologies and techniques." (Seyfang and Smith, 2007, p. 585). These communities exist in social economy, which is in contrast to the market economy motivated by two alternative driving forces, by social need and ideology. They are created to fulfill the needs of the community and to serve ideological purposes (Seyfang et al., 2010).

In the empirical section (Section 3) of this paper a specific type of grassroots initiatives will be presented, namely renewable energy communities, which, as we will argue, form an internally oriented niche. Renewable energy communities, in contrast to mainstream society, aim for clean energy production at local level, since they are driven by a common social need, namely to produce energy independently and by different values, such as environment protection, patriotism by supporting the local economy, or the value of working for the community. Hence their primary goal is to meet these expectations, which the community has been set up for and innovations (both technical and social innovations) are the tools serving these purposes. Thus they have no direct aspiration to develop innovations for later regime use, but only for internal utilization. Consequently, renewable energy communities, as an internally oriented niche, aim for self-sustainment and not necessarily for transition. However, before introducing them we devote the last part of this theoretical section to the transition potential of niches, namely how niches can scale up and induce transition.

2.4 Scaling up and establishing links with the regime

We have argued so far that the break-through of the technology is accompanied by all the innovations that actors developed, and transition may occur through a regime shift created by the entire niche. Therefore, niches are not seen as necessarily protected spaces for radical novelties, but they are seen as entire systems themselves, even if they are less stable and more malleable. At the same time they also have to build up and co-evolve with some similar, but already existing sub-regimes that are willing to accept them, and these sub-regimes see this link-up with niche actors as an opportunity for their own further development.

The most important question here is, when we can talk about transition. What is the turning point when these small systems leave the niche level and become an integral part of the ST regime? Certainly, social groups that are different from the incumbent regime actors, because they share different values or social needs, can have a maximum of their capacity for growing (Seyfang and Smith, 2006). However, without the capability of attracting more and more people from the regime they will never break out of the niche level. Thus only niches that are heterogeneous enough in terms of the variety of innovations they use (e.g. within the broad category of renewable energy communities, different groups can use wind, solar, biomass or other. technologies depending on their special needs and resources), the motivations of the actors and the conditions they are operating under, have the potential for regime transformation.

Seyfang and Smith (2007) distinguish two types of grassroots innovations. The first one does not seek to transform the regime and remains in the grassroots niche and the other one can diffuse and change the regime (Seyfang and Smith, 2006). Grassroots innovations that position themselves in opposition to the incumbent regime and share specific ideology, thereby forming homogeneous groups, have difficulties to scale up and attract a wide range of actors from the mainstream society. While those that can create a new 'system of provision', generate transformation in production and consumption patterns and create new institutions that can provide better solutions for a large variety of actors within the regime, have the capacity for transition. In conclusion, the less ideology-based the group and the larger the variety of actors regarding their motivations, location and conditions, the higher the chance that different social groups can identify with them and are willing to adopt their practices and solutions. However, their existence alone is certainly not enough to induce transition.

On the one hand, landscape changes can trigger value shifts at the regime level, or changed environmental conditions can lead to adoption by the regime of innovations and solutions that were shared so far only by a few people in specific social groups. On the other hand, changes within the regime, such as internal technical problems, changing user preferences or competition between firms, can also result in the creation of ‘windows of opportunities’ where innovations can break-through (Geels, 2004). Thereby all parts of the niche with all the technical and social elements can find their connections in the regime. In case certain social groups in sub-regimes see the potential or the matching points with them, they can start building up links and involving different elements of the niche, in this way making the niche elements part of the regime. Consequently, the breakthrough of the niche and its transition can take place if it is able to attract a large number of regime actors and to create strong links with social groups in the sub-regimes. By this means the niche is partly building up on the existing regime, but at the same time it alters it and shifts it to a new direction.

In summary, niches can be considered as complex systems rather than only as protected spaces, that are built up from several coevolving elements. Accordingly, during the transition not only one element of the niche (e.g. technology) gets into the regime, but the whole system induces a regime shift. Furthermore, the ST regime may be more fragmented and compounded than the MLP has described it so far. Contrary to the original definition, its sub-regimes are formed by not only one but different social groups (e.g. different technologies in the technological regime, different demand-side groups in the user regime, different levels with sometimes different interests of decision makers in the policy regime (EU, national level)), which are linked in diverse ways and with various strengths, thereby composing in a way separate – though not disconnected – systems. Transition occurs when the niche is able to make its links with social groups of the incumbent sub-regimes that are open for this change. Certainly, changes at landscape level and within the regime, as the MLP explains, trigger the opening up of these groups, but windows of opportunities do not arise in every part of the system and other segments can remain closed and resistant. The more and stronger links the niche is able to set up, the stronger its position becomes in the ST regime, which is more likely to result in a successful transition. Despite that this process generates change and rearrangement within the entire ST regime, it does not necessarily lead to the replacement of the ST regime as a whole, since demands of other groups can be still better met by the old sub-regimes. Certainly adequate governmental policies could foster change in the interest of these groups, too.

In addition, while externally oriented niches especially intend to establish links with the incumbent sub-regimes and thereby become an essential part of the ST regime, the aim of internally oriented niches is not primarily the break-through to the regime. However, in order to be able to create and maintain their internal systems they have to possess appropriate technologies, infrastructure, user practices and rules. Consequently, they have to enter into relations with social groups in the incumbent sub-regimes that can endow them with the indispensable tools and settings. In this way even unwittingly they create links with them and as a result in case they attract other social groups in the regime, they become part of it and the transition takes place.

Should renewable energy communities be considered as separate niches or as one coherent niche? Raven et al. (2010) have illustrated how separate local projects connect with each other by starting to network, exchanging knowledge, helping each other in learning, organizing platforms, conferences, other common activates and introducing standards and rules and thereby becoming a niche. Hilscher et al. (2011) argue further that instead of treating these groups as small niches we can deem them as one ‘global level’ niche, since all of them focus on sustainable energy regardless that they are distributed spatially and temporally. Following these interpretations I also consider renewable energy communities as one niche.

In the following section we will demonstrate that renewable energy communities form one internally oriented niche, which has the potential for inducing transition, since they show a strong diversity in terms of technologies, motivations of its actors, group sizes and locations. In consequence, they have the capacity to attract a large variety of actors from the regime. Finally, we will demonstrate the links that this niche has already built up with certain sub-regimes and in case of adequate governmental support it could become a substantial part of the future energy regime.

3. Renewable energy communities

The empirical analysis of this section is based on systematic literature and documentary review including reports and websites of organizations dealing with renewable energy communities. This data was then examined using the elaborated framework of the multi-level perspective outlined in the previous section. Besides that we conducted four case studies in the Netherlands based on 22 semi-structured interviews with members of renewable energy communities. The scope conditions for our research population were: 1) communities that are located in the Netherlands that invested in renewable energy, 2) the investment is a citizen initiative, 3) the members of the initial investment community (people who bought the technology) live in the same location/region, 4) all the members of the investment community that realized the investment are shareholders in all or at least one of the technologies. We used distribution-based case selection to demonstrate the variegation of renewable energy communities.

As a first analytical step we assess, whether these communities can be considered as niches and to what extent these energy communities form one coherent niche. Taking the example of renewable energy communities in the Netherlands we can see that all the niche elements that turn them into a small system are present. Citizen initiatives dealing with energy are rooted back to the end of the 80s in the Netherlands. There are no precise data relating to the number of Dutch renewable energy communities; however, we can estimate that it lies somewhere between 150 – 300 (Schwencke, 2012). Regarding their form and activity they show a large variety: initiatives that invest mainly in solar PVs by doing collective procurements, groups that invest in windmills and become shareholders, others that set up co-operations in order to operate biomass power plants or heating installations based on geothermal energy. In some cases a complete energy company grows out from the local co-operations, which supplies energy not only to its members, but also to other customers – examples are Grunniger Power, Texel Energie or Thermo Bello.

Although renewable energy communities usually work independently and try to develop their business plans for the procurement and installation of the technology on their own, today there are already several platforms, networks and organizations that provide help for them and create websites, write newsletters and organize workshops or education clubs (HIER opgewekt, Nieuwe Nuts Innovatie Netwerk, Wij krijgen kippen, LDEB, Rescoop, Organisatie voor duurzame energie, E-decentraal, Stichting ODE, Energie plus), where communities can learn from each other and be up to date about all the important aspects and news that are necessary for their establishment and operation. In this way separate communities get to know each other, form a social network and facilitate learning to adopt the best practices and to cope with problems.

And not just already organized communities find help for their projects, but also several campaigns exist for collective procurement in order to incentivize people to buy solar PVs collectively (Windvogel, Zeeuwind, Urgends, Betere Wereld, Natuur en Milieu, vereniging Eigen Huis, ZonEffect, MetdeZon, Zutphense Energie Transitie, SolarBlitz). Nudge has for example a specific campaign, in which they are looking for so-called district mayors, people who would gather local citizens and organize the procurement of solar PVs for them with help from Nudge, thereby facilitating the creation of new renewable energy communities.

Other organizations (e.g. Zon op Nederland) facilitate communities, whose members have no space for installing solar PVs on their own properties, to collaborate with farmers or institutions (schools, offices) that can have their roofs rented by the community. One example is Energie van boer en buur, a citizen initiative which together with farmers invests in solar PVs that are installed on the stables and sheds of the farmers. In its first version citizens contributed €250 to the project, for which they got vouchers in the value of €300 for which they could buy products from the farmer. In the second version of Energie van boer en buur there are 27 farms involved throughout the country and the community members invest €300 in exchange for shares and electricity supply (Schwencke, 2012). In many cases these campaigns and organizations grew out of local initiatives, and solutions/procedures that a renewable energy community used once pass on to the others. In this manner they create patterns and new practices that become knowledge capital of the niche.

However, the most important and striking example showing that these communities form a niche system and share common goals, is the organized lobby work aimed at the government for the extension of the so-called 'saldering' law. Currently, people are not allowed to supply the electricity for themselves if it is not produced behind their own meters. It means that in case the electricity installation is not located on the property of the owner, but somewhere else and the produced electricity is fed into the grid, the person has to pay VAT and energy tax above the electricity price that he could sell the energy for, when he buys it back. In case the electricity is produced on the owner's property, the producer is exempt from the taxes and VAT up to 5,000 kWh per year. This is called 'saldering' (which can be translated as: 'balancing'). However, the regulation hinders not only individual investments in case they lack space for the installation on their own property, but also collective energy production. Therefore, several renewable energy communities together with other organizations such as the Wij krijgen kippen, Windvogel, Klimaatverbond, Amsterdam Stadsdeel Zuid with the support of companies (e.g. Greenchoice, Liander, ASN,) and university professors wrote a petition and take all opportunities to lobby for the extension of saldering for also collective self-supply.[1]

Reviewing all these examples we conclude that renewable energy communities can indeed be regarded as one complex niche system which encompasses all the elements that can be found also in the ST regime. Furthermore, they are also a locus of not only technological, but also social innovations regarding new practices and behavioral patterns. Moreover, as it was argued above, since these communities' primary aim is 'green' energy production for meeting their local needs, they can be considered as an internally oriented niche that creates a protected environment for innovations that serve inner purposes.

3.1 Renewable energy communities as transforming niches – capacity for scaling up

Turning to the second step of analysis we will discuss whether renewable energy communities compose a transforming niche. In other words, we are interested whether they have the potential for scaling up, creating links with the regime, trigger changes in its sub-regimes and attract different groups of regime actors. Walker et al. (2006) claim that this sector lacks a common goal, a shared vision and that there is no intention for the replacement of the incumbent energy system. In addition, these communities show

[1] http://www.wijkrijgenkippen.nl/wp-content/uploads/2011/04/Green-Deal-verruimde-saldering-13-april-def.pdf

diversity in terms of technologies, projects, organizational forms, motivations and actor groups. That is why they are “remaining firmly in their expanded but not transforming niche” (Walker et al. 2006, p. 13). However, we do not share this view, that the diversity of these communities and the lack of common goal (which is not even the case if we consider the extended lobby work for collective saldering) prevent them from transforming the regime. On the contrary, we believe that the higher the diversity of the niche the more links it can develop with sub-regimes and the more people it can attract from the entire ST regime.

Certainly, the niche of renewable energy communities is very varied and diverse. We conducted case studies in the Netherlands with four renewable energy communities. Our case selection is not representative in a sense of presenting typical renewable energy communities. It aims rather to demonstrate the variety of these communities, in order to underpin our above mentioned argument. We found that all communities are different in their size (ranging from small communities with a few members to large communities having 3,000 members), in their location (an island, a house-boat neighborhood in Amsterdam, a district of a small town or a dwelling house), in the technology they use (solar PVs, water pumps, wind mills and a starting project on a biomass power plant) and in their motivations (financial, environmental, helping the local economy, being independent from big companies and the hedonic motivation of working together with fellow citizens on a joint project). The communities are the following:

The biggest community studied is located in Texel, an island in the north of Holland with a population of 13,644 inhabitants. A bit less than one fourth of the local citizens are members of the renewable energy community, which has grown into an energy company. Texel Energy delivers renewable energy, electricity and gas to businesses and private clients in Texel and in the rest of Nederland. Texel Energy buys and sells not only renewable energy, but also produces it from solar PVs, windmills and currently they are also working on a biomass and a smart-grid project. The idea of Texel Energie was conceived by three local citizens who wanted to support the local economy and help the island to become sustainable. After the involvement of 9 other residents they started the energy initiative in 2007. The news spread like wildfire on the island and by the end of the first year 600 people joined the project and now there are 3,000 shareholders of the company.

The house boat neighborhood in Amsterdam Zuid constitutes the second renewable energy community studied, which has 50 members. Four local people started the project in 2008 when they wanted to buy solar PVs for their own, but they got an offer from a supplier that in case they buy PVs in large quantities they could get them at a reduced price. That is why they involved people from the neighborhood who found the option of environment friendly energy production attractive, and the project became a big success. Therefore, the collective procurement was repeated in the two following years.

Our third case is a residential community in a dwelling house in Leeuwarden. 11 households from the building participated in the project, which was initiated by two residents who wanted to make use of the large roof by installing solar PVs. The energy they produce is used by the whole building (association of the owners) and not by individual households; the rest of the energy is sold to the grid. Their main motivation was producing clean energy to protect the environment, besides that they found it exciting to work together and they wanted to gain some profit too.

Our final case is different from the previous ones in the sense that the community produces heat and not electricity from renewable energy. Thermo Bello is a district heating company owned by residents in the district EVA Lanxmeer, which is located in Culemborg, a small town near Utrecht. The story of Thermo Bello started in 2006, when Vitens, a public water company wanted to sell its subsidiary, a local heating system. The company distributed heat occurring in the process of cooling down drinking water. The director of Vitens wanted to sell the heating system as soon as possible. Since there was no big company interested in this system at that time, even though he offered it much under market price, he also asked the local municipality and the association of house owners whether they wanted to buy it. Although the municipality didn't show any interest, there were four residents who saw the potential in it and decided to investigate the option of setting up a local energy company and taking over the heating system. 68 people from the neighborhood participated in the project and contributed either financially or actively to the process. They had diverse motivations. Firstly, they were afraid that Vitens would sell the heating system to a big company that would increase the heating prices and not give the residents any control. Secondly, they saw it as a challenge and they found it exciting to realize such a project. Finally, they also had ecological reasons. By local management they can save a lot of energy which is good for the environment.

Our cases show also intra-case diversity in terms of the people who participated in the projects. Firstly, we met heterogeneous motivations in each of the cases. Most of the people claimed that the protection of the environment was their main intention for participating in the project, but also expected financial benefits played an important role in this decision. Besides that, people who actively participated in the organization process found it a good opportunity to get to know their neighbors and do an inspiring and creative project with them. Moreover, newcomers found it a great opportunity to get accepted by the community and make their integration easier. Secondly, each case is rather heterogeneous in terms of the education, financial capital and age of the people. The community in Amsterdam Zuid is the most striking example of that, since there we can find, on the one hand, the old, mostly lower educated working-class residents that moved to the house-boats neighborhood in the 60-70's, because they did not want to fit in the framework provided by mainstream society. On the other hand, the second generation of the inhabitants are rather wealthy intellectuals that could afford to live in luxury house-boats in the capital of the Netherlands.

This variety of location, size and technologies shows that the niche of renewable energy communities is heterogeneous, encompassing diverse groups driven by different motivations. Consequently, participating in a renewable energy project at community level can be an option for many people. Hence, we can conclude that renewable energy communities form an internally oriented niche that has the potential to spread and gain an essential part of the user sub-regime.

3.2 Renewable energy communities as transforming niches – creating links with sub-regimes

However, not only the potential for scaling up has to be examined for measuring whether renewable energy communities compose a transforming niche. The capacity of a niche to build many and strong links to the sub-regimes is also important, which – even when unintended – can trigger changes in the entire ST regime. As a final step of our analysis we will study how these communities perform in this sense.

In general renewable energy communities in the Netherlands could establish links to several sub-regimes. Firstly, there are several governmental and provincial measures to support the establishment of such communities or help their operation. Green Deals are especially targeting them by eliminating obstacles. Firstly, the government provides financial help for initiatives through the MKB+ Innovation Fund and tax deduction for research and development. Secondly, the government helps as mediator in matchmaking and negotiating with all parties involved in a community project. Finally, it tries to reduce unnecessary administrative work and other legal obstacles. Furthermore, at provincial and local level we can also find cases when the government contributes to the realization of community projects. The municipality of Amsterdam, for example, started a pilot project that provides an alternative solution for the lack of collective saldering law. The residents of an apartment complex can do virtual saldering after the electricity produced by their solar PVs set up on the roof.

And not only the government supports renewable energy communities, but also companies see the potential in this niche and establish links with them. Greenchoice and Aliander, for example, offer specific leases and loans, they help in the administration of local energy cooperatives, or also find alternative solutions for collective saldering. Windvogel supports financially the local energy initiatives. Trianel, Eneco and Anode offer support services, act as intermediaries, use their formal and informal networks in lobbying for self-supply or make Green Deals with them. Moreover, in case a community is not able to organize the project itself and needs additional help, there are also several consultancies that are specifically helping local renewable energy projects, such as Relocal, C8 foundation, Eversheds Faasen. Finally, there are several banks, like Triodos bank, Rabobank, ASN bank that give special loans and also services. Rabobank has specialists that support energy cooperations and Triodos organizes a masterclass about financial models for energy initiatives.

In our cases we also saw many examples for cooperation with regime actors. In Culemborg the local municipality invested €3,000 in the Thermo Bello project and it also gave a financial guarantee to the bank after for the loan (€70,000); thereby the community could get a two percent lower interest rate from the bank. The alderman helped them to lobby at the provincial level; thereby they could achieve that the Province of Gelderland supported the expansion of the pipelines with €150,000. In the case of the dwelling house in Leeuwarden, the local government provided an expert who helped the community in the project. When the residents from the houseboat area from Amsterdam wanted to invest in solar PVs, the technology supplier saw the potential in a community project and offered reduced prices if the people did collective procurement. Finally, the community in Texel cooperated with a local energy company whose professional help was crucial for the realization of such a project.

As we see there are different links established with the regime. The policy sub-regime regards renewable energy communities as such important factors of energy transition that it creates policies for their support and actors from different governmental levels provide financial and professional help for their investments. There are also actors from the market, distribution and financial sub-regimes that see the potential in these communities and help their establishment and operation by providing loans, support services, or by using their official and in-official networks for lobbying in their favor to the government. Finally, NGOs and associations that operate in the socio-cultural sub-regime and try to change the carbon dependency of the ST regime from inside of the regime, look at renewable energy communities as a potential alternative of the fossil based energy system and therefore they support them and set them as examples for incumbent regime actors.

4. Discussion

Transition to sustainability is one of the biggest challenges of the 21st century in case humanity wants to avoid the dramatic consequences of climate change and depleting fossil resources. Therefore, a better understanding has to be gained on how clean innovations can take over the place of incumbent technologies and in which ways carbon lock-in can be resolved. The multi-level perspective provides an analytical framework for studying this complex process and the nature of the existent socio-technical system. However, there are still several blurry spots in the theory regarding the structure of the regime, the description of niches and how transition can take place in a modern market-economy.

Thus, the aim of this article has been to further elaborate the MLP by concentrating on these questions, which were dealt with using the example of renewable energy communities in the Netherlands. Contrary to the theory, we claimed that niches are not just protected spaces for the development of innovations, but that they are complex systems themselves, in which the co-evolvement and joint break-through of the elements trigger changes in the regime. Transition, however, does not necessarily mean a complete regime shift to another one, since the ST regime itself is not an unitary whole, but rather an interlinked system of several sub-regimes. Thus, changes in some segments do not necessarily lead to the whole transformation of the regime and both technical and social innovations can coexist with incumbent ones. In addition, each sub-regime is further fragmented by different social groups having different interests and orientations. Links between diverse social groups from divergent sub-regimes compose the structure of the regime and during transition new links are established with niches, which thereby become a new segment of the entire system.

We also made a distinction between internally and externally oriented niches referring to their focus and purposes. While externally oriented niches develop innovations especially for later regime use, internally oriented niches aim primarily for satisfying inner needs and innovations serve only these ambitions. These small systems become transforming niches in case they are able to attract a wide range of actors from the incumbent regime and establish strong links with different sub-regimes. However, the intention for their transformation is not a compulsory requirement for transition. To demonstrate this, we took the example of renewable energy communities in the Netherlands, a special type of grassroots innovations, and we argued that they are internally oriented transforming niches, that even without primarily aiming at transition they can build up links with the incumbent regime, and that they have the capacity to scale-up and trigger changes. Although this process does not necessarily lead to a complete regime shift, renewable energy communities have the potential for becoming an important part of the current energy system and contribute to the transition to a sustainable market-economy.

As final remark, we have to note here that in case renewable energy communities wildly spread in the regime and a very large number of communities decide to invest in renewables, it may result in problems affecting the operation of the electricity grid. The current energy system is tailored to centralized and large-scale energy production, which is not yet able to bear and balance fluctuating energy supply. That is why, without the restructuration of the whole system, the large spread of renewables and thereby renewable energy communities is impossible. The concept of 'smart grid' could provide a possible solution for this problem. Further empirical investigations can explore how the development of a 'smart grid' could help the spread of renewable energy communities either in case of a national or several local 'smart grid' projects.

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Smart meter communication standards – a barrier for the transformation towards a smarter grid?

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Abstract

For new technological fields to emerge, standardization is of crucial importance. However, firms can be expected to pursue and defend their strategic interests by supporting opposing standards. In this paper, we take a closer look at the adoption and development of smart meter communication standards, which are essential for the development of smart electricity grids. We analyze the strategic interests of different actors and discuss the impact these diverging interests have for the field. The analysis shows that there are a large number of competing standards supported by different constituencies. The conflicting interests can be explained by different kinds of resources and specific competences the firms want to use as complementary assets in the novel field. As for now, strategic alignment and standard convergence is not in sight. This seriously hampers the development of the field as, for example, economies of scale and network effects cannot be realized.

1. Introduction

Smart Grids are considered a major innovation in the energy sector. They promise ecological and economic benefits and therefore seem to be a desirable transition towards sustainability. Nevertheless, smart grids are not widely diffused yet.

Missing interoperability standards have been identified as a key barrier for the diffusion of smart grids (OECD / IEA, 2011). Common, international standards are needed to ensure interoperability, seamlessly connecting different parts of the grid. Moreover, international standards are expected to realize economies of scale and reduce costs and thereby create mass markets (OECD / IEA, 2011). To overcome this barrier, numerous activities have been started by policy makers, firms and academic scholars. In 2009, the EU has given a mandate to three European standard development organizations (SDOs), to develop a smart meter (M/441) and smart grid (M/490) standard framework and to identify and develop missing standards. As a consequence, SDOs and participating firms have increased their standardization efforts in smart grids. In parallel, different industry associations and national as well as international SDOs have published standardization roadmaps (e.g. VDE / DKE, 2012) and proposed smart grid standards.

Academic research has contributed by describing and comparing existing standards (Rohjans et al., 2010; Feuerhahn et al., 2011; Güngör et al., 2011) and identifying gaps. Moreover, scholars have proposed new frameworks and proposed solutions for compatibility and interoperability between different standards (DeBlasio and Tom, 2008; Rohjans et al., 2010; Lehnhoff et al., 2011).

However, no assessment has been made so far, whether these activities achieve the desired goal of driving the development and diffusion of smart grids in Europe. For such an assessment an analysis of the status of smart grid development is necessary as well as the standardization activities going on. Two streams of literature provide the theoretical background for such an assessment. Firstly, literature on sustainability transitions and innovation systems and secondly, the literature on standardization from management sciences.

Sustainability transitions literature (Geels, 2002; Farla et al., 2012) and research on innovation systems (Carlsson et al., 2002; Malerba, 2004; Markard and Truffer, 2008) help to understand the processes of transformations of socio-technical systems and the emergence of new technological fields. Several functions, such as legitimacy creation or sufficient resource mobilization, have been identified as important processes in the development of new fields

(Hekkert et al., 2007; Bergek et al., 2008). Moreover, the importance of institutional change is strongly emphasized (Geels, 2002, 2010). However, standards as specific institutions have not yet been analyzed in detail.

In management literature, standards have been in the focus of many different studies. These studies provide helpful insights into micro (firm level) and macro (environmental) forces of standards and standardization (Narayanan and Chen, 2012). They provide an understanding of how technological standards both drive and are driven by actors, mostly firms, in the field (Garud et al., 2002; Suarez, 2004; Narayanan and Chen, 2012). Standards shape the environment in which firms act. Common standards increase legitimacy for new technologies (Garud et al., 2002), reduce investment risks for users, create positive externalities in terms of network effects (Stango, 2004; Economides and Katsamakas, 2006) and as result create new markets (Funk and Methe, 2001; Garud et al., 2002; West, 2007). At the same time, firms can use standardization as a way of building competitive advantage. Especially proprietary standards yield high, unshared returns for standard sponsors. These returns come at the expense of legitimacy, which makes wide diffusion of proprietary standards more difficult compared to open standards. Open standards, however have their own challenges, they are quasi-public goods and therefore create a free-riding dilemma for sponsoring firms (Olson, 1965). The creation of competitive advantage is therefore more complex in this case (Garud and Kumaraswamy, 1993; Garud et al., 2002; West, 2003, 2007).

In this paper, we build on these theoretical insights and analyze the interrelation between standardization strategies of firms and the diffusion of smart grids in Europe. More precisely, we focus our analysis on smart metering communication standards. We do that for three reasons: Firstly, smart meters are the first and so far the only smart grid technology widely deployed in the field (Pike, 2011; Giordano et al., 2013). Secondly, two-way communication is a key technology to make the grid smarter. It allows reading status information from distributed devices such as meters and it allows sending commands to these devices. Thirdly, communication standards ensure or inhibit interoperability between different components in the network. And interoperability is essential to generate positive network effects.

The paper is structured as follows. In the next chapter, we provide the theoretical background on the role of standards for field development and firm strategy. In section 3, we describe the development of smart grids in Europe and introduce the main players (firms). In section 4, we present the results of our analysis of smart grid communication standards including their development and adoption. Then we discuss the results and their repercussions for the development of the field. Section 6 concludes.

2. Theoretical background

2.1. Technical standards and strategic relevance of standardization

Standard are "*rule*(s) *for common and voluntary use, decided by one or several people or organizations*." (Brunsson et al., 2012). Typically, technological standards are developed by firms individually or collectively in so-called standard development organizations (SDOs) and industry alliances. Users are often less involved in standard development, especially when complex technologies are concerned (Funk and Methe, 2001), but they ultimately decide about standard adoption.

Firms invest in standard development and diffusion, because they strategically intend to shape their environment to achieve competitive advantage (Besen and Farrell, 1994; Garud et al., 2002; West, 2007; Narayanan and Chen, 2012). They are successful, if 'their' standard is commonly adopted by users (Funk and Methe, 2001).

Commonly adopted standards can create competitive advantage (Funk, 2003) by making a firm's resources more valuable (Narayanan and Chen, 2012) or other firms' resources less valuable (McWilliams et al., 2002; Gallagher, 2007; Narayanan and Chen, 2012). A firm's resource endowments might allow one firm to implement a standard faster and at lower cost than a competitor. A firm's resources might also be better suited to develop complementary resources based on the standard.

In a similar vein, a commonly adopted standard can also become a barrier for entry, when the resource investments to fulfill the standard are too high (e.g. because of economies of scale) (Salop and Scheffman, 1983; Garud and Kumaraswamy, 1993; McWilliams et al., 2002; West, 2007). This is also the case if a commonly adopted standard is proprietary in nature. The owner of the intellectual property or patents can limit access to the market (West, 2007).

Firms can pursue several strategic approaches for creating competitive advantage based on standards. On the two extreme ends, there is a proprietary strategy (Cusumano et al 1992) and an open standard strategy (West, 2003). In between, there are several semi-open approaches (West, 2007). These are often committee-based approach, where open standards are developed in SDOs or industry alliances (Funk and Methe, 2001). Each strategy has distinct mechanisms for creating positive returns for the investment in standard development (Besen and Farrell, 1994; West, 2007). The investment in proprietary standards have protected and unshared returns for the firm (West 2003). Moreover proprietary standards create high switching cost for users and thereby establish market entry barriers for other vendors. Microsoft's Windows Operating System (Windrum, 2004; Eisenmann et al., 2006) and JVC's VHS (Cusumano et al., 1992) are well-known cases. However, with such a strategy firms might struggle to gain legitimacy.

Strategies based on open standards enjoy higher legitimacy but the creation of competitive advantage is less obvious (Garud and Kumaraswamy, 1993) as open standards do not allow for proprietary returns and do not create lock-in effects. Competitive advantage can nevertheless be realized e.g. through complementary assets (Funk, 2003) continuous standard development, short innovation cycles or the acquisition of tacit knowledge in the standard development process (Garud and Kumaraswamy, 1993). Moreover, viable functional strategies have been identified such as a customer service focus, an innovative product design, or increased engineering efficiency (West, 2003). Sun's sponsorship of Java as an open standard (Garud and Kumaraswamy, 1993; Garud et al., 2002) illustrates this case.

In SDOs, a firm can create competitive advantages by proposing its technologies as a standard. In case the proposal is accepted, the case firms enjoys several advantages, it has a time advantage as it has already developed and deployed products that comply with the standard, whereas others still need to adapt their products accordingly (West, 2007). It has also a resource advantage as it has already build up the necessary competencies to build products / solutions based on this standards (West, 2007). Finally, the company enjoys the reputation of having 'its' technology accepted as a standard. Like other open standards, SDO developed standards enjoy high legitimacy and often broad adoption (Funk and Methe, 2001). However, not every proposal is accepted by the members of the SDO. Competing proposals might exist and a consensus among members might need to be worked out. In this case the competitive advantages of firms might shrink.

Standardization literature also provides some insights into the conditions under which firms support which of these strategies. A proprietary strategy can be successful, only if users accept possible lock-ins. Moreover, only very strong firms (market leaders) can pursue such a strategy, as they need to have the resources to develop the standard alone and to achieve wide diffusion (West, 2003). Strategies based on open standards are open to all firms. However, firms that traditionally pursued proprietary strategies are found to have difficulties to successfully implement open strategies (West, 2003).

Finally, on a more general level, Besen and Farrell (1994) find that similar firms tend to follow the same standardization strategy. Moreover Brunsson and Jacobsson (2000) conclude that similar firms tend to support similar standards.

2.2 Relevance of standardization for field development

The presence or absence of common standards can drive or block the development of a new field in several ways (Garud et al., 2002). Standards are rules of the game or institutions in theoretical terms (Geels, 2002). Like other institutions, standards need to be adapted to allow for sectoral transformation (Geels, 2002; Malerba, 2004). Existing institutions create stability for the prevailing system and create momentum along a continuous technological trajectory (Hughes, 1987). Hence, they can constrain innovation. New, missing standards need to be created and existing once need to be replaced, changed or complemented to achieve transformation. New standards have to compete against existing standards for legitimacy of evaluation criteria and the mobilization of resources.

New standards can serve as a vehicle to create legitimacy for a new technology (Garud et al., 2002). Legitimacy creation is an important pre-requisite for new technologies to diffuse (Hekkert et al., 2007; Bergek et al., 2008). Standards create legitimacy for users to invest, especially when they are open (e.g when developed by an SDO). This legitimacy is further enhanced by mandates of national governments or the European Union (e.g. M/441 for smart meter standardization).

In addition, new common standards can be a pre-requisite for resource mobilization of users. For new technologies to grow and diffuse, resources need to be mobilized (Hekkert et al., 2007; Bergek et al., 2008). Common standards give users security for investment (West, 2007), whereas missing standards can be a reason for users to hold back investments (Besen and Farrell, 1994). Users might also hold back investments if available standards are proprietary and they must fear vendor lock-in if they adopt the standard.

Beyond these implications for the speed of field development, standards might also have an impact on the direction the development trajectory takes. Some standards might be more inducing for subsequent innovation than others. Open standards for example can fuel innovation and growth. Through their openness they are quasi-public goods (Blind and Thumm, 2004) and therefore decisive for the diffusion of new technologies. Moreover, open standards lower the entry barriers for new technology suppliers into the field. With more actors active in the field, competitive dynamics and variety is likely to increase (West, 2007). Variety is a key driver of innovation (Nelson and Winter, 1982). Also the design of a standard can shape the direction of field development. Certain standards might build the basis for more radical innovation and transformation of the field than others.

However, common standards might also create path dependencies. Once a standard is widely adopted, bandwagon effects are created due to increasing network externalities (West, 2007). Once the winner has taken it all, path dependencies or even lock-ins are created as the cost for change become extremely high. If the "winning" standard is proprietary or if the chosen technology limits the possibilities for future innovation (e.g. too narrow bandwidths), such paths dependencies can hamper further transformation of the field (Brunsson and Jacobsson, 2000). On the other side, if standards are designed in a future-proof way, they can be a fertile ground for further innovation and transformation (Brunsson and Jacobsson, 2000; Garud et al., 2002).

Ultimately, the positive effects of standards on field development can only unfold under certain conditions. These conditions are only partly in the interest of firms. Firstly, *standards need to be developed*. Therefore actors need to invest resources in standard development and technology vendors need to implement them in their products (West, 2007).

But firms will only invest in standard development, if the expected returns are high enough. In other words, they invest, if the market is sufficiently attractive (large and profitable) and if they can create competitive advantage through standardization.

Secondly, *standard adoption needs to converge to one common standard* to create positive effects for the field. Commonly adopted standards increase legitimacy for new technologies, create positive network effects and lead to decreasing prices thanks to economies of scale (West, 2007).

This is generally positive from a firm perspective as it unlocks user investment and thereby creates markets. Convergence, however will only take place, if one standard wins over others. That can mean that some firm(s) can create competitive advantage as a result, whereas others cannot. It seems therefore unlikely that firms with different sources of competitive advantage will drive convergence. Convergence is rather driven by users, creating bandwagon effects, resulting in the common adoption of one standard.

Thirdly, *standards should be rather open* to foster innovation through creation of variety (Nelson and Winter, 1982) by new entrants and competition.

While users and the field development generally benefit from open standards, firms that develop standards might not. It is easier for firms to generate exclusive returns, if the standard is less open (Olson, 1965; Funk, 2003; West, 2007). We therefore can expect firms to pursue an open strategy, only if there are strong drivers to open up. Such drivers can be missing user acceptance of open standards or policy pressures.

Finally, *standards should be future proof* with respect to the further transformation of the field. Standards should be designed to prevent premature obsolescence and facilitate future upgrades and functionality (OECD / IEA, 2011). Otherwise switching cost become too high and innovations might become victims of path dependencies.

Firms however, need and want short-term revenues for their survival and growth. They will push technologies and standards that are cost competitive today (Hoppmann et al., 2013) and close to their existing resources and can be implemented immediately regardless of the impact on future field development. For firms, path dependencies can translate into desirable customer lock-in situations and entry barriers for others.

3. Background on smart meter field development and firms

3.1. Smart meter development in Europe

Smart meters are the first and most-widely diffused smart grid technology, so far (Pike, 2011; Giordano et al., 2013). This development is re-enforced by a goal of the European Commission (EC) to have 80% of households equipped with smart meters by 2020. Countries have to realize this goal under the condition that a cost benefit analysis (CBA) shows positive returns (Directive 2009/72/EC). Each country therefore has to conduct a CBA and translate the EU goal for their local context. National smart meter policies are the consequence. Several countries have chosen to mandate the roll-out of smart meters others count on voluntary implementation by utilities. Most of the policies designed so far, are rather neutral with respect to technology. They focus on goal setting or cover functionality and privacy regulations. Only UK (DECC) and Germany (BSI) have prescribed the technologies for smart meters in their policies.

Overall, only few countries have completed the smart meter roll-out today. Italy was the first country to roll-out smart meters in 2001, even before the EC set its goals. Finland, Denmark and Sweden followed with their roll-outs from 2003 on. Sweden and Denmark even proceeded with their roll-outs despite a negative CBA (Giordano et al., 2013). To date, these are the only European countries that have completed their roll-outs. Several other countries including France, Spain, UK and Netherlands have decided to go forward with the implementation and partly also started the roll-out, but have not finalized it yet (Giordano et al., 2013). Again others (Belgium, Czech Republic and Lithuania) have decided against a smart meter roll-out, based on a negative cost-benefit analysis (Giordano et al., 2013)**.**

The driver for smart meter roll-outs differ significantly between countries. While Italy aimed at avoiding non-technical losses (electricity theft), Sweden rolled out smart meters to comply with a new regulation that makes monthly billing of customers compulsory.

Beyond goal setting, the EC also drives standardization efforts. In 2009 the EC gave a mandate to three European standardization organizations CEN, CENELEC and ETSI to elaborate smart grid (M/490) and smart meter (M/441) standards. To this end the three SDOs set up a smart meter coordination group. In 2011 they issued a first technical report mapping out a functional reference architecture and existing as well as missing standards. The report revealed areas of overlap between existing standards and only few gaps. In the second phase the coordination group focuses on the development of European Standards including harmonized solutions for additional functionalities within the previously defined architecture.

3.2. Firms involvement in smart meter development in Europe

Smart meter communication standards are developed mostly by private firms individually or collectively in SDOs or industry associations. Numerous different firms are active in the field of smart metering (Erlinghagen and Markard, 2012). In the following, we provide background on different groups of firms. We group the firms according to similar histories and resource endowments.

Traditional meter manufacturers form the first group of firms. These firms have a long history (60-120 years) in development and production of electricity meters. They started off with analog 'Ferraris' meters and now have a complete portfolio of digital smart meters. Typically these firms are not diversified, they focus on metering only.[1] In the past, the meter

[1] The portfolio typically only includes different types of meters such as electricity water, heat or gas meters.

market was extremely fragmented and meter firms had strong local focus. Over the years, consolidation among traditional meter manufacturers has taken place. Firms like Landis+Gyr, Itron, Elster or Iskramaeco emerged as major firms in this process. Through acquisitions they extended their scope to regional or even global scale. These firms traditionally have strong ties with their customers, the metering department of utilities or more specifically of DSOs. They have the competencies and an organizational set-up to develop meters to the specifications in each country or even for individual (large) customers.

The emergence of smart metering is a major growth opportunity for these firms and at the same time a threat for their core business. The growth opportunity is twofold. Firstly, the replacement of conventional meters with smart meters happens in one big wave and thereby temporarily boosts the meter market. Secondly, smart meters can be considered a springboard to smart grid markets. To realize these growth opportunities and counter the threat for their core business, traditional meter firms acquired small communication technology firms to build up necessary communication competencies (Erlinghagen and Markard, 2012). Going forward traditional meter firms can strategically leverage their existing strengths, which are metering hardware, strong ties to customers and the ability to serve local markets according to their needs.

With the advent of digital and smart meters new players entered the market. One part of new entrants offers metering hardware and communication others focus on communication only. *New meter manufacturers* typically have a less complete metering hardware portfolio. Instead they put (strategic) focus on communications. Many of these firms have only national or regional presence. Firms like Echelon, SagemCom, Aidon, Dr.Neuhaus, Görlitz fall in this category. They are typically comparably young firms (at most 30 years) with diverse backgrounds, many of them with some sort of information and communication technology (ICT) background.

The second part of new entrants only *specializes on communication* technology. These firms do not develop own metering hardware. These firms are in average even younger. PowerPlusCommunication in Germany or Connode in Sweden and Finland are examples here.

As new entrants in the field, these two sub-groups of firms typically position themselves with (slightly) different value propositions than traditional meter manufacturers. They strategically highlight their competencies in ICT. They typically have little experience and resource for standard development.

Telecommunication Operators like Vodafone or Deutsche Telekom and *telecommunication equipment manufacturers* like Cisco, Alcatel Lucent or Huawei form another group of firms active in smart meter communication. In the past, these firms enjoyed growth in their home sector. Today however, their markets start to saturate, e.g. in mobile phone sales and usage in many developed countries (Newswire Today, 2009; MobiThinking, 2012). Therefore they now intend to expand their markets by making machines (e.g. meters) instead of people talk to each other. These so-called M2M strategies target multiple sectors, the automotive and energy sector being among the most prominent ones (OECD, 2012). Many telecommunication operators have established separate business units or even separate legal entities to develop M2M business (OECD, 2012).

Their strategy is an exploitative one. They try to utilize their existing communication infrastructure (mobile phone and wired internet connections) and technological competencies in other markets. The spin-off M2M activities in separate business units however shows that a distinct focus (e.g. in technological features, business models or go-to-market approach) is needed to address these new customers (OECD, 2012). When it comes to standardization, telecommunication firms have a long history of experience in SDO based standardization processes (Funk and Methe, 2001). In the early days each region defined its own mobile phone standards. But with every generation, the standards became more global. For the current generation (GSM) and the next generation (LTE) telecommunication firms have agreed on one global standard. For this purpose regional SDOs from North America, Japan and Europe joined forces (Funk and Methe, 2001).

Finally, the last group of firms is *utilities*. As operators of distribution systems they decide which smart meter communication standard they want to adopt for their network. Utilities typically do not sell any hardware or communication products but get involved in standard development as users of smart meters. This is in line with historical developments. In the past, large utilities specified requirements for their meters and did not buy ‘off-the-shelf’ products. A similar pattern can now be observed for smart meter communications. ERDF in France, Enel in Italy and Iberdrola and Endesa in Spain are particularly active here. Enel even goes one step further by developing and selling own metering hardware and communications.

Overall, many actors from different backgrounds are involved in the field of smart meter communication technologies. These firms not only come from different industries but also possess different sets of resources, infrastructures, competencies and expectations with regard to the development of the novel field. In other words, they have very different starting points for creating competitive advantage based on smart meter communication standards.

4. Results: Smart meter communication standards

4.1. Adoption of smart meter communication standards in Europe

Our analysis of the adoption of smart meter communication standards in Europe reveals that there is a high degree of heterogeneity. So far, more than 10 different standards have been used.[2] Communication standards do not just vary across but also within countries. The map in Figure 1 shows which standards have been adopted in which countries. For the diffusion of communication standards utility companies have played a central role as they decide on the scale of the meter rollout and the standard(s) to be used. Some utilities have even implemented various standards in their network (Vattenfall in Sweden and also Tampere in Finland installed LONWorks and DLMS/COSEM standards).

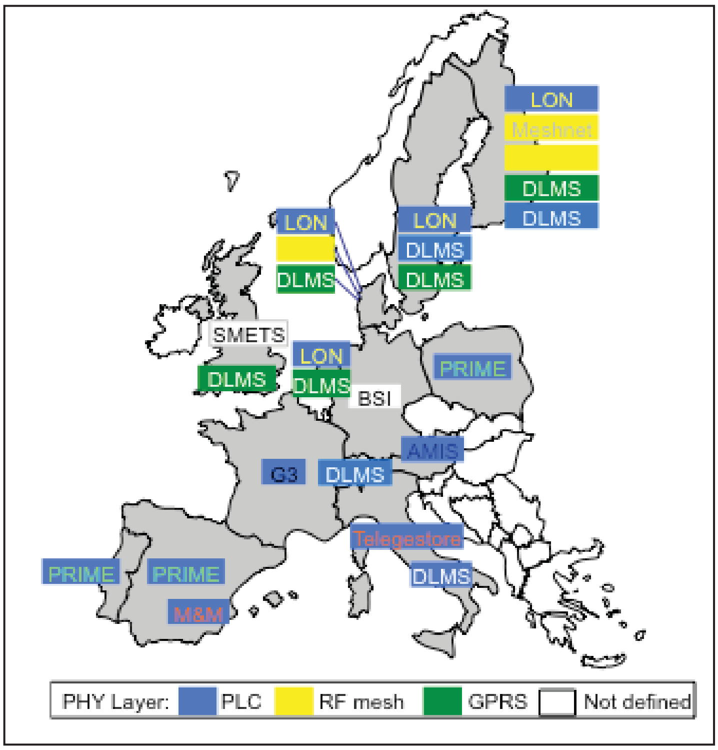

Figure 1: Map of standard adoption (includes installations / decisions >50.000 meter endpoints)

[2] See next section for a description of the standards.

Interestingly, the largest European countries introduced different (national) standards. In Germany the FNN[3] defines a standard according to the national protection profile (BSI), in France ERDF will roll-out the G3 standard and Iberdrola will implement the PRIME standard in Spain and Portugal. Enel implemented the Telegestore project in Italy, which now has evolved into the Meters&More standard that will also be implemented in parts of Spain by Endesa. Finally, the UK government mandated the so-called SMETS specification for smart metering. Smaller countries like Sweden or Finland did not define own standards but implemented standards proposed by SDOs (IEC) or vendors like Echelon.

This heterogeneity will prevail for some time, as the expected lifetime of meter installations is 15-20 years. The first roll-out in Italy was completed in 2001 but most of the other roll-outs only happened after 2005 and many have not started yet (Giordano et al., 2013).

The analysis also shows, that many standards that were installed in the past (2001-2009) are proprietary[4]. These include many of the LONWorks and Meshnet installations in the Nordic countries, the Telegestore project in Italy and the AMIS projects in Austria. Only the DLMS based installations in the Nordic countries have used an open standard. More recent standard adoption decisions, in contrast, have mainly been in favor of open standards such as G3 in France, PRIME or Meters&More in Spain and the DLMS based project of British Gas.

Finally, our analysis reveals that utilities have mainly selected narrow-band power line communication (PLC) standards in Europe. We identified two reasons for this selection. Firstly, PLC technologies currently enjoy cost advantages over other physical communication technologies. Secondly, it allows the utilities to own and operate their own communication network. In other words, utilities seek to have full control over the communication and not depend on third parties (as in the case of mobile phone communication). These two criteria seem to be more important to utilities than advantages in bandwidths that other technologies like mobile phone communication could provide (see next section for technical background on standards).

In the following, we take a closer look at all standards selected by utilities so far (as listed above) excluding the government-imposed, mandatory standards defined in Germany and the

[3] FNN is a German national standardization organization in the electricity sector.

[4] A standard is considered proprietary if some parts of its specification are not freely accessible for third parties or if it is protected by patents

UK. In addition, we include some rather recently developed standards to capture the latest developments in the field.

4.2. Technical comparison of existing standards

Understanding the reasons for standard development by firms, the adoption by users and the implications for the field development is a complex task, which requires a basic understanding of the technical characteristics of standards. Here we provide basic technical background information on communication standards. This will allow for a technical comparison of the standards.

Smart meter communication standards define rules or conventions for the information exchange between devices (meters and backend systems) in a network. These rules include specifications of syntax, semantic and the synchronization of communication in so-called protocols. Typically such protocols contain among others rules for data and address formats for data exchange, address mapping, routing, detection of transmission errors, direction of information flow etc.

Communication protocols need to function in divers settings, for this purpose they are typically structured in layers. The Open Systems Interconnection (OSI) model is widely used for structuring protocols. The OSI model consists of seven layers. The lower layers (physical and data link layer) determine the physical communication medium (fiber cable, powerline, radio frequency (RF) etc), the upper layers (session, presentation and application layer) determine the functionality. The layers in between enable the transport (see Figure 2). We use this layer model to compare which layers are specified in which smart meter communication standard.

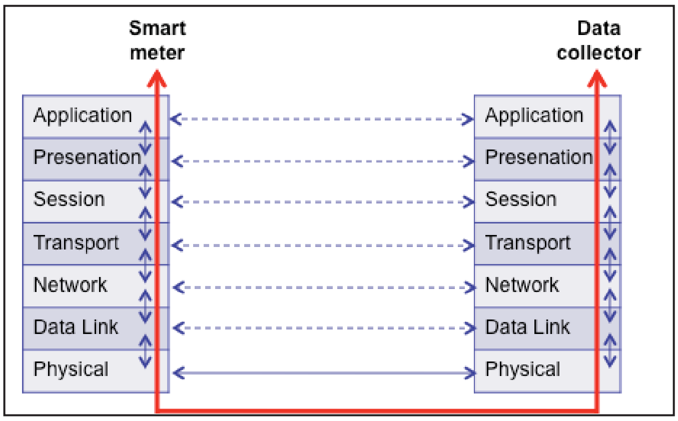

Figure 2: Communication technology based on OSI model

We focus our analysis on meter communication standards that establish the link between the meter and the so-called data concentrator that collects the metering information of a group of meters in a certain region. This type of communication network is typically referred to as local area network (LAN).[5]

In the following, we compare the characteristics of the twelve different standards included in our study with the help of the OSI model (see Table 1). This overview reveals the competing nature of these standards, but it also shows complementarities. Some of the standards can be combined or re-use parts of other standards. For example, DLMS/COSEM can be combined with P-LAN and also with G3. The PRIME standard and Meters&More re-use some parts of the P-LAN standard.

More specifically, the comparison shows that most standards use narrowband power line communication (PLC) as physical communication layer. Six of these standards focus on narrowband PLC only. They describe mainly the lower layers of the OSI stack. They include P-LAN, ITU P1901.2, IEEE9955/6, Prime, G3 and AMIS. These standards represent several generations of PLC technology: P-LAN[6] belongs to the first generation; PRIME, G3 and AMIS belong to the next generation. The current developments of ITU (P1901.2) and IEEE (9955/6) claim to contain even more advanced in their technology features.

Another set of standards focuses more on the upper layers of the OSI stack and claims flexibility with regard to the physical communication layer. DLMS/COSEM does not specify the lower layers at all and claims to be the most flexible. LONWorks, OSGP and M&M specify the lower layers (using PLC), but claim to also support other physical layers such as wireless communication e.g. via cellular networks. Most implementations of these standards are however done using PLC. A third set of standards is explicitly designed for wireless communication i.e. cellular or RF mesh. The Meshnet standard and the oneM2M standards are examples here. While the Meshnet standard defines the radio frequency (RF) communication on the lower OSI layers, the M2M standards re-use existing (mobile) telecommuncation standards on the lower layers and focus on the application layer only to provide M2M or energy specific functionality.

[5] We do not include the communication between data concentrators and the backend system (wide area communication WAN)

[6] the PLC technologies described in Telegestore (now Meters&More) and LONWorks can also be considered first generation PLC technologies

Standard / OSI Stack	P-LAN	AMIS	IEEE P1901.2	ITU 9955/6	PRIME	G3	DLMS/COSEM	Meters&More	LONWorks	OSGP	Meshnet 3	ETSI M2M
7 Application						IEC 62056-6-2 IEC 62056-6-1 IEC 62056-5-3 (IDIS)	IEC 62056-6-2 IEC 62056-6-1 IEC 62056-5-3	Meters&More	LONWorks	ETSI GS OSG 001	Meshnet 3	TR 102 691
6 Presentation									LONWorks			
5 Sesssion									LONWorks			
4 Transport						UDP: IETF RFC 768	TCP/IPIEC 62056-47		LONWorks			
3 Network						IPv6: IETF RFC 2460	IP Network		LONWorks	ISO/ IEC EN14908-1	IPv4	IPv6
2 Data Link	IEC 61334-4-32 IEC 61334-5-1	CX1	IEEE P1901.2	ITU 9955	IEC 61334-4-32 + Prime MAC	6LoWPAN Adaptation: IETF RFC 4944 + MAC SubLayer IEEE 802.15.4 - 2006		Meters&More adapted IEC61334-4-32	CSMA*+ CRC: CCITT CRC-16		Meshnet 3	GSM, LTE, DSL, etc
1 Physical		CX1 (shift key transmission)	IEEE P1901.2	ITU 9956	ITU G.9904 Prime PHY OFDM Modulation	ITU G.9903 G3 PHY OFDM Modulation		Meters&More BPSK Modulation	RS-485; Echelon free-topology (FT) PLC; +other	ETSI TS 103 908		

Table 1: Comparison of smart meter communication standard along OSI model

The choice of the physical communication layer (lower OSI layers) in a standard has consequences for bandwidth and latency[7] of the communication. As shown above, most standards use PLC as a physical communication medium. Narrowband PLC has a low bandwidths (several hundred bit/sec up to 576 kbit/sec) and a rather high latency (reaching every end point might take several minutes). Broadband communication technologies such as wireless standards for mobile communication (GSM or LTE) or wired standards such as DLS have higher bandwidths (>1Mbit/sec) and lower latencies. Today, narrowband PLC solutions have cost advantages for users, but the restrictions in bandwidth and latency might become a bottleneck for future functionality (OECD, 2012). Solutions (such as short term balancing with primary reserve) that function based on real-time information for instance require low latencies.

4.3. Modes of standard development

On a non-technical dimension, our analysis revealed that standard development is organized in several different ways. Standards are developed by different organizations: different SDOs (see Table 2 for an overview of national and international SDOs), industry alliances or individual firms. The way how standards are developed often has consequences for the degree of openness of the standard. Standards developed by SDOs are typically open as the SDO makes openness a pre-requisite for standard acceptance. A standard is developed and accepted in a process with clearly defined rules. Standards developed by industry alliances can be more or less open depending on the rules the alliance has given itself. For example, access can be restricted to members of the alliance only (Meters&More is an example here). Standards

[7] Latency is a measure for the delay between the sending and receiving of a signal.

developed and sponsored by individual firms are not governed by pre-defined rules. In many cases standards of individual firms are proprietary (at least in some aspects).

Sector	National Standard organizations	European standard organization	International Standard Organization
Electrotechnology	ANSI (USA), DKE (GER), etc	CENELEC	IEC
Telecommunication	N/A	ETSI	ITU
all other	ANSI (USA), DIN (GER), etc	CEN	ISO

Table 2: Overview of national and international standard development organizations (SDOs)

We observe a clear trend towards open, SDO developed standards. But many standards are still developed by industry alliances or individual firms. P-LAN and DLMS/COSEM as well as oneM2M were developed by SDOs from the start. In addition, DLMS/COSEM standard is co-developed by the DLMS user association. Other standards like PRIME or G3 were initiated by industry alliances but were recently approved by an SDO. The LONWorks standard has been developed by Echelon as a single firm. More recently, Echelon launched the open smart grid protocol (OSGP) and ESNA as an alliance to develop OSGP as a vehicle to open up its standard. The OSGP standard has now also been accepted by ETSI. The AMIS standard by Siemens and the MeshNet standard by Connode are other examples for standard developments by individual firms. Like in the case of LONWorks the sponsoring firms now start to open up their standards or build new versions of their technology on existing standards. Table 3 summarizes the different characteristics for the standards under consideration.

The table not only reveals the competing nature of these standards, but also the competition between different international SDOs. While PLAN and DLMS/COSEM are developed by IEC, Prime and G3 have been accepted by ITU. The latest generation of PLC standards is now developed by IEEE and ITU. The cellular M2M standards are developed by ETSI and other telecommunication standardization bodies. SDOs often represent whole sectors (see Table 2). In the case of smart grids, however, the sectoral boundaries are blurring (Erlinghagen and Markard, 2012).

Dimension . Standard	Developed by	Type of development org	Initial openness	Current openness	Comment	Physical Comm. Layer	Bandwidths/ Latency
P-LAN	CENELEC / IEC	Intl SDO	open	open	only maintenance	PLC	low/high
AMIS	Siemens	Individual firm	proprietary	open	now discussed in CENELEC	PLC	low/high
IEEE 9955/6	IEEE	Intl SDO	open	open	only draft available	PLC	low/high
ITU P1901.2	ITU	Intl SDO	open	open		PLC	low/high
PRIME	Prime Alliance, ITU	Industry alliance and SDO	open	open	only accepted as companion standard	PLC	low/high
G3	G3 Alliance, ITU	Industry alliance and SDO	open	open	only accepted as companion standard	PLC	low/high
DLMS/COSEM	CENELEC / IEC	Intl SDO	open	open	M/441 tested, basis for IDIS	several options	N/A
Meters&More	Meters&More alliance	Industry alliance	Proprietary*	open to members	M/441 tested, only Enel produces meters	PLC default**	low/high (default)
LONWorks	Echelon	Individual firm	proprietary	open	only Echelon produces chips	PLC default**	low/high (default)
OSGP	ESNA, ETSI	User alliance and SDO	open	open		PLC default**	low/high (default)
Meshnet	Connode	Individual firm	proprietary	open	Next version based on IEEE 802.15.4g	RF Mesh	low/high****
ETSI M2M	ETSI M2M	European SDO	open	open	further developed in global oneM2M	several options***	high/low

*Telegestore **exchangeable **broadband ICT standards ***restricted by European regulation

Table 3: Standard characteristics

4.4. Analysis of firms' standard development activities

In this section we take a closer look at which (groups of) firms support which standard(s). Analyzing the constituencies behind the various standards provides us with first insights into the strategic interests different players have in the field. Moreover, we might also be able to draw conclusions about the relative power of the different alliances and the corresponding effects for future developments.

Our analysis shows that the actors groups identified in section 3.2. develop and support different smart meter communication standards. They undertake several activities to develop and support these standards for distinct strategic reasons.

Traditional meter firms support the metering standards of IEC that existed already before meters were becoming smart (DLMS /COSEM and P-LAN)[8] as well as utility-driven standards i.e. the PRIME standard by Iberdrola and the G3 standard by ERDF. Interestingly though, they do not support the Meters&More standard driven by Enel and Endesa. The (likely) reason for this is that Enel started to produce and sell meters itself and thereby became a competitor of traditional metering firms.

Especially the top-five meter firms are highly active in standardization. They lead standard development initiatives like P-LAN and DLMS and are founding partners of the utility-driven

[8] P-LAN and DLMS/COSEM were used for industrial, commercial and grid meters in the past. These meters became ‚smart' in the 1990ies. This is also when the standards were developed.

standard development initiatives PRIME and G3. Furthermore three traditional meter firms (L+G, Itron and Iskramaeco) formed an additional alliance (IDIS) based on the DLMS/COSEM standard. The alliance was formed in the course of the first larger smart meter tender by ERDF. From the start, the goal of IDIS was to ensure 100% plug and play interoperability between their products. Today, the strategy goes further and promotes IDIS as an interoperability approach for several different protocols on the lower layers of the OSI stack and harmonized DLMS/COSEM layers on the upper layers of the stack.

New meter firms show a different pattern in their standardization activities. They do not engage in the development of classical metering standards or utility driven standards. Instead, they develop and support the diffusion of standards such as LONWorks and OSGP, or they rely on third party communication such as mobile phone standards. Few of them also participate in the DLMS/COSEM user association.

The most successful firm of this group is Echelon. Echelon developed the LONWorks standard initially for broad automation purposes. But they were successful mainly only in two fields building automation and later also metering (Rossi et al., 2009). In 2003, Echelon acquired a metering hardware firm and thereby became a meter vendor itself. Echelon actively tried to diffuse their LONWorks standard by selling it directly to utilities and licensing it out to third parties, with some success as Figure 1 shows. Echelon's LONWorks is said to be open (published by ANSI in the US), but Echelon is the only supplier of chips compliant with the standard. This allows Echelon to earn returns, when other vendors use their technology. In parallel, Echelon created the OSGP alliance also builds on LONWork technology.

Other new meter manufacturers such as Aidon or Görlitz also use LONWorks or OSGP, but they typically have a divers portfolio of communication technologies they implement. Many enable wireless communication based on mobile phone communication technologies (esp. GSM) and RF mesh. Moreover, they provide interoperability solutions between otherwise incompatible standards (e.g. Görlitz integrates the L+G meter which is typically based on DLMS in an LONWorks/OSGP network).

SagemCom is an exception in this group. Sagem supports all traditional metering standards as well as the utility driven standards including even the Meters&More standard driven by Enel. SagemCom rathers acts like a traditional meter manufacturer except from the fact that it also supports the Meters&More standard.

New entrants that specialize on communication offer niche solutions such as broadband powerline communication or RF mesh technologies. These types of communication are not widely diffused in Europe because of higher cost for broadband powerline and regulations in the case of RF mesh[9]. These firms are small and have little resources for standardization. They join existing standardization efforts, if the activities help grow their niche.

Telco firms joined forces to establish a global machine-to-machine (M2M) standard, the so-called oneM2M alliance. In this alliance worldwide SDOs of the telco sector work together to develop M2M standards in general and a dedicated smart meter use case in particular. These standards focus on the description of the upper OSI layers and rely on traditional telecommunication and IT standards such as GPRS or LTE for the physical layer and IPv6 for the transport layer. The oneM2M initiative tries to repeat the successful global standardization effort of mobile phone standards GSM and LTE (Funk and Methe 2001). The oneM2M initiative was only founded in July 2012. Before, SDOs like ETSI and individual firms like Vodafone already started developing M2M standards for metering. ETSI now proposes their recently developed M2M standards for global acceptance oneM2M. Vodafone is the telecommunication operator with the largest smart meter deployment in Europe so far. Their deployment at British Gas is however uses GPRS communication (for the lower layers) in combination with DLMS protocols (for the upper layers).

Beyond the oneM2M standardization effort, some telecommunication firms also engage in standard development efforts driven by traditional metering firms and utilities. Deutsche Telekom is part of DLMS user alliance, Cisco is part of IEC 61334 SDO and G3 alliance and Huawei is part of PRIME alliance. The participation of Cisco in the G3 alliance is likely to be explained by the fact that G3 is the first PLC standard to use IPv6, which is at the core of Cisco's strategy of pervasive usage of internet protocol (IPv6). One possible reason for the other exceptions is a strategy of knowledge transfer. Telco firms have to build up energy specific knowledge to be successful in this field. Another possible reason is the influence of these standards to enable compatibility with products or solutions of telecommunication firms. The DLMS standard for example already today is compatible with GSM communication as physical layer.

Large national *utilities* drive the development of own standards. They develop the standards for their home country but also for broader diffusion and 'export' to other utilities and

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[9] In Europe very few frequency ranges are made available for metering use.

countries. ERDF in France develops the G3 standard, Iberdrola in Spain the PRIME standard and Enel in Italy (together with Endesa[10] in Spain) drive the so-called Meter&More standard. While Iberdrola and ERDF are just about to start their roll-outs now, Enel already finalized a large scale meter roll-out, the so-called Telegestore project[11], in 2001. Only in 2011, the Meters&More standard was developed based on the Telegestore technology. Before 2011, the Telegestore technology was proprietary. Enel successfully sold this technology to other Italian (e.g. A2A) and international (e.g. Malta) utilities. In contrast to Telegestore, the Meters&More standard can be considered as rather open. It is accessible to the members of the alliance. Meters&More is however not developed by an SDO. The PRIME and the G3 standard have recently been accepted by SDOs. Interestingly, these two standards have been accepted by ITU, which is a telecommunication standardization body (compare Table 2), rather than IEC, the traditional "energy" standardization body.

All three utility-driven standards have in common that they use PLC. This reflects the preference of utilities to own the communication infrastructure for their meters and do not want to rely on third parties such as mobile operators.

In summary, we find that different groups of firms support different standards, with very few exceptions (Sagemcom and Cisco). Between these groups there are only few overlaps. The struggle for a dominant smart grid communication standard, in other words, is fought between groups of similar firms rather than among firms in the same industry (Brunsson and Jacobsson, 2000). Only the DLMS/COSEM standard and its user association seem to build a bridge between different groups of firms. This is in line with the finding that the DLMS/COSEM (among others via the IDIS association) attempts to achieve compatibility with several other standards.

5. Discussion

5.1. Firm standardization strategies

Our findings allow for the interpretation that different groups of firms have different sources of competitive advantage in smart meter communication standardization. *Traditional meter*

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[10] Endesa is owned by Enel

[11] Initially Echelon supplied its LONWorks technology to Enel. But the partnership broke up in 2003 (see Rossi et al. 2009).

manufacturer (seem to) build on their past success with existing metering standards (P-LAN and DLMS/COSEM) and develop them further in SDOs they have worked with in the past. In the respective working groups of these SDOs, they enjoy large influence and can develop standards in the direction that allows them to create competitive advantage. They can build on the already existing legitimacy of those standards in the field. This legitimacy stems from the long existence of these standards and the legitimacy of IEC as an accepted SDO in the sector and their open character. It is further strengthened by the M/441 mandate of the EU, which strengthens the role and legitimacy of European standardization organizations.

The standardization strategy of traditional meter manufacturers builds strongly on the DLMS/COSEM standard. While P-LAN might at some point be replaced by newer generations of PLC standards, the DLMS/COSEM standard seems to have increasing strategic value. Traditional meter manufacturers have successfully achieved wider acceptance and support for the DLMS/COSEM as an application layer and thereby created legitimacy (Garud et al., 2002). Moreover, the IDIS association seems to try to leverage this legitimacy of the DLMS/COSEM standard for its strategy to build a bridge between several lower layer standards.

In addition, traditional meter manufacturers leverage their traditionally close relationships with the metering departments of utilities to develop metering standards jointly with large utilities. One part of the competitive advantage gained is rather obvious: such an engagement strongly increases the likelihood for participating firms to win the (large) utility as a customer. However, it also means, that a different communication standard needs to be supported for each large utility. This typically increases costs. But traditional meter manufacturers can leverage their traditionally strong local presence and use it to create competitive advantage. On top of that, the country and regional difference might even be desirable for meter manufacturers to some extend as they can create entry barriers for new entrants with a more global set-up (including competitors from low cost countries) or for smaller firms who cannot afford to build different meters specifically for each market. The desire to keep entrants out is also reflected in cooperation patterns. While traditional meter manufacturer cooperate with each other in standard development, they do not cooperate with new entrants like new metering firms and telco firms.

New meter and communication firms mostly support different standards than traditional metering firms. This allows for the conclusion that they try not to compete on the same grounds as traditional meter firms. Instead, they develop alternative communication standards that allow them to differentiate based on communication technology. This is an area where they have equal or even more competencies than traditional meter manufacturers. Therefore, new entrants build value propositions around the superiority of their technology whereas traditional meter firms argue based on accepted, open SDO standards. These firms tried to protect their returns by keeping some parts of their standards proprietary. The pressure towards open standards initiated activities of opening-up the standards.

Echelon, as one of the most successful new entrants, has build parts of its business model on licensing out communication technology standard to other new meter vendors. This business model relies on the fact that they own intellectual property rights (IPR) and/or are the only supplier of LONWorks chips. The parallel creation of the OSGP alliance by Echelon and the acceptance by ETSI is an effort of opening up and creating legitimacy. While ETSI, as a SDO from the telecommunication sector, might be the natural choice for Echelon, thanks to its ICT background, ETSI however is less influential in the energy sector, so far.

By developing and promoting M2M standards, *telecommunication firms* aim to re-use their existing resources, more specifically their installed mobile phone communication networks. Smart metering seems like an all or nothing game. When they cannot use their existing telecommunication infrastructure, it might not be attractive for them to enter the field of smart grid. Unlike other groups of firms, the value proposition of telecommunication firms is cross-sectoral, i.e. it can be applied in several sectors including metering, automotive, etc. In scenarios where meters are integrated into wider infrastructures e.g. so-called smart cities, this aspect becomes increasingly relevant. Moreover, this wide application should allow them to benefit from substantial economies of scale in the future.

Utilities as standard developers and users, play a dual role. At first glance, it is surprising that users play such a strong role in standardization. In this case, however, users are very large organizations (in comparison to a typically fragmented user base that is difficult to organize). By pro-actively developing standards, utilities ensure that they get exactly the meters and communication they want. Moreover, utilities can use own metering standards strategically to sustain their regional dominance and position themselves in a changing energy market. Moreover, standards can be a way of extending their reputation to other regional markets. Iberdrola for example “exports” the PRIME standard to Portugal and to utilities in South America.

Both, Iberdrola and ERDF, successfully tried to get their standards accepted by an SDO. This does not only help them to create legitimacy but is also a vehicle to get their standards more widely adopted. Like in the case of OSGP, both standards are however accepted in ITU, a SDO from the telecommunication sector with less influence so far in the energy sector.

Specification of own metering standards seems irrational at first sight. Typically users should have an interest in wide diffusion to create network effects and drive costs down through economies of scales (West, 2007). Large utilities however, have enough scale (35 mio. meters in France) to create economies of scale and have strong bargaining power.

5.2. Implications for field development

We will discuss the implications of standard development for the development of the field based on the four criteria identified in chapter 2: Standards need to be developed, commonly adopted, open and future proof to create positive effects for field development. In a second step, we will discuss the reasons for this outcome in the light of firm standardization strategies.

Firstly, we find many firms actively engaging in standard development and many standards being developed. Hence, there does not seem to be a lack of resource investment in standard development in Europe. Just the opposite: firms seem to perceive smart metering as an attractive market, which is worth the involvement in standardization. A consequence of this attractiveness, however, is that different firms compete with regard to the standard they want to establish and diffuse.

Secondly, many different standards have been adopted throughout Europe and convergence to one standard is not in sight. The decisions of early-moving utilities (like Enel in Italy or Vattenfall and E.ON in the Nordic countries) were not imitated by others. Instead, many other utilities have created their own standards. So far, only few developments, such as the interoperability activities around DLMS/COSEM and IDIS, are in favor of potential convergence. As a consequence, the entry barriers into smart meter communication remain rather high for technology developers. The fulfillment of one standard opens up only small parts of the market and fulfilling several different standards is costly. The observation that especially new entrants only operate at local or at most regional scale supports this argument. In summary, the missing convergence of standards is a barrier for the development of the field.

One reason for this missing convergence can be found in the big differences in firm backgrounds and the resulting different sources of competitive advantage. Standardization can be an all or nothing game for some firms. Telecommunication firms might step back from the smart metering market, if they cannot re-use their existing competencies and installed infrastructure (e.g. mobile phone networks). Smart meter firms might be reduced to the role of hardware suppliers, if telecommunication firms like Vodafone or Cisco build and manage communication networks. It might therefore be more import for firms to push for the own standard (and keep rivals out) than to allow for convergence and development of the field.

Another reason for missing convergence can be found in the dual role of utilities. If large utilities develop their own standards, they guarantee adoption at least in their ‘territory’. If several, especially large, utilities do this as shown above; this automatically creates a heterogeneous picture throughout Europe, which is difficult to revise.

Thirdly, many of the standards developed today are open and owned by SDOs. Even those that are not accepted by SDOs (yet) started opening up. This should create positive effects for the legitimacy of the new technology and can avoid the risk of vendor lock-ins for utilities. However, many installations in the field happened before these standards were developed, so they are still based on proprietary standards. These past installations have already created path dependencies as swap outs of technology are costly and installed meter infrastructures are typically expected to last for 15-20 years.

Finally, our analysis has also shown that PLC technology is the dominant physical communication medium used on Europe. While this technology is the most cost efficient and allows utilities to be independent from third party communication providers, it is restricted in bandwidths and latency (Güngör et al., 2011). This restriction might limit future functionality, such as real-time metering (OECD, 2012).

Given these findings, we expect that the unresolved struggle on communication standards together with the ongoing rollouts of smart meters in Europe is not favorable for the development of the field as a whole.

6. Conclusion

We have shown that smart meter communication standards represent a critical issue and a hot spot of strategic activities in the development of smart grids in Europe. Standard adoption in Europe is a patchwork of many different standards, with no convergence in sight. While actual roll-outs of smart meters are dominated by proprietary standards, more recent deployment decisions have been in favor of open SDO standards. Moreover, we also found that the majority of actual and planned deployments use narrowband PLC technologies that might restrict more advanced, real-time functionality in the future. Jointly, these past choices are barriers for the development of smart grids and might even create path dependencies due to the long lifetime of meter technology.

We have also shown that many firms with different backgrounds and interests invest in standard development and struggle for dominance. Firms with similar backgrounds work together to raise the entry barriers for other firms. These conflicting strategies will be difficult to overcome, because the ownership of (different) complementary assets is at the core of the strategic interventions in the field.

In addition, we have highlighted the dual role of large utilities as standard developers and users, which even increases the number of competing standards and further hampers convergence towards one standard.

Since neither users nor suppliers seem to drive convergence, policy makers might want to consider stronger interventions. The EC mandate (M/441) seems to have a positive effect on openness of standards, but it has not lead to convergence, so far.

Our research has shed some light into the underlying causes that prevent firms from developing common standards in the area of smart meter communication and elsewhere: where complementary assets of strategic importance exist and intense struggles for dominance in the field are ongoing the chance of settling standard 'wars' are rather dim.

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User involvement in niche experiments. A study of Dutch experiments in electric mobility

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Key Words: learning, niche experiments, electric mobility, user, user involvement

Abstract

Electric vehicles are a promising technology for a more sustainable mobility system. Experiments in protected spaces play an important role for stimulating system innovation towards electric mobility. For successful niche experiments, the shaping of expectations and multiple learning processes are important elements. First- and second-order learning is necessary to learn both from the technology and about preferences and the social embedding of the technology in society. Users play an important role in such experiments. This research sheds light on how interactions with users are shaped in niche experiments with electric vehicles in the Netherlands. On the basis of 21 interviews in four cases, we learned about experiment setup and user involvement. We found that providers of niche experiments have difficulties in selecting (the right) users for their experiments and have too little focus on interactions with the users. We found that users have a lot of knowledge about the technology and the experiment they are a part of, but also that the experimenters had difficulties to extract what the users learned. Most experiments had a strong focus on technological learning, despite the important role of users in societal learning processes.

1. Introduction

Electric mobility is recognized as a promising technology in the transition towards sustainable mobility. Several experiments are executed in the Netherlands with electric cars (I&M, 2011). Goals of these projects are to learn how the technology works in practice and which aspects can contribute to make electric driving a success.

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Experiments in protected spaces –in technological or market niches – are a first step for new technologies before they can enter mainstream markets (Geels and Raven, 2006). When new technologies emerge, they normally show a low performance, high costs and there is no stable network to support them. In niches that are protected from fierce market selection, new technologies can develop and co-evolve with the socio-technical environment in which they are intended to function. Three important processes in niche experiments are the building of social networks, learning and articulation processes and the articulation of expectations and visions (Geels and Raven, 2006).

The setup of such experiments should be in line with the learning goals and it should be clear what mechanisms of the new technology are tested in the experiment. A clear focus and a vision for an experiment are crucial when articulating goals and selection criteria for the experiment (Raven, 2006). It is argued that user involvement contributes to successful niche experiments. One would say that providers should focus on enthusiastic users that have some feeling with the new technology. These 'lead users' are on the forefront of a trend, are open towards the new technology and should use it in some kind of an extreme context (Lettl, 2007; Von Hippel, 1986). Experiments should emphasize the importance of learning about user preferences, the social desirability of the technology and legal frameworks in an early stage of a transition (Truffer et al., 2002; Geels and Schot, 2007; Nill and Kemp, 2009). Interaction with users offers the opportunity that the user's needs are articulated effectively and that the acceptance of the technology is improved.

Not all users are able to give sufficient feedback in radical innovation (Letll, 2007; Von Hippel, 1986). It is therefore important to carefully select the users involved in experiments and to think about the way of interacting with these users. Hoogma et al. (2002, p. 191) saw that many SNM experiments related to transport suffered from weaknesses, especially related to obtaining knowledge about user needs and the conditions for alternative mobility; users generally played a passive role in the experiments. In general, we see that there is still a lack of knowledge about what users to involve in niche experiments, and about how learning from these users should be optimized. This also raises the question in what way the interaction with users is currently shaped in experiments.

The research question we address in this paper is: how are users involved in Dutch electric mobility experiments, and how is this related to our theoretical knowledge of adequate user involvement in niche experiments? The research is based on a multiple case study approach: four experiments with electric mobility in the Netherlands were analyzed. The analysis relates to the goals and the practical set-up of the experiments, the selection of users, and the feedback that was obtained from these users. The goal of this paper is to compare the setup of actual niche experiments with the theoretically known conditions for the proper involvement of users in experiments, to arrive at recommendations for further research and to give practical advice on how to involve users in such experiments.

In the next section, we give a short literature review on niche experiments and user involvement in innovation processes. Section 3 contains a conceptual model and a methodological description of the research. Case descriptions and results are given in section 4 and analyses are given in section 5. The paper ends with conclusions and recommendations in section 6.

2. Theoretical Background

The introduction of new, sustainable technologies is a burdensome process. The transport sector, for instance, witnesses such struggles with the electric vehicle and with the hydrogen vehicle. An important barrier is that new technologies do not fit well into the existing transportation systems (Hoogma, 2002). The new technology may require complementary technologies or infrastructures. But also many other aspects of the new technology are not yet developed. The new technology cannot compete technologically (in terms of performance) with current technologies while the price will also be (too) high (Geels and Raven, 2006). The technology may not fit in existing regulations and cultural and psychological barriers exist (Kemp et al, 1998). Another problem, specific to technologies with an improved environmental performance, is the fact that the environmental benefits will accrue to the whole society, while the higher cost price will be incurred by the adopter of the technology.

The introduction of such technologies requires a socio-technical development process, in which the technology and the system in which it has to function (slowly) become aligned. The strategic niche management (SNM) approach has been developed in order to steer and guide the introduction of radically new technologies in existing socio-technical systems (Kemp, 1998; Geels and Raven, 2006). Hoogma et al. (2002) have developed and used the SNM approach in relation to several transport innovations.

Strategic niche management (SNM) focuses on the way niches can be created for technology and market experience in such a way that the derived knowledge is adequate for diffusion into the current socio-technical regime. After (1) the choice for a technology, (2) the selection and (3) set-up of the experiment, it can be (4) scaled up and if the potential is high enough, (5) the protection of the niche can slowly be broken down (Kemp et al., 1998). A balance should be found between protection and selection pressure in order to reach the goals of the experiment: “learning about the desirability of the new technology and enhancing the further development and the rate of application of the new technology” (Kemp et al., 1998, p. 186). Good experiments contain several processes: the shaping of expectations, the building of social networks and multiple learning processes (Raven, 2005).

The first process, the shaping of expectations is based on the expectations of most stakeholders that will participate in the niche experiment. Especially in the early development of a technology, the articulation of the expectations must be properly done since it can attract resources and new actors (van der Laak et al, 2007). Well formulated expectations are shared by multiple actors, specific and substantiated by ongoing projects (Elzen et al., 1996; Hoogma et al., 2002). The second process is the building of social networks. Again, this is important in the early stages of a technology. A social network around a technology should be built by a broad range of actors that interact with each other on a regular basis (Raven, 2005; van der Laak et al., 2007). The third process is about multiple learning processes, and of the utmost importance in experiments. Learning should be broad and not only focused on technological and economic factors. Social factors like user preferences should be a focus of a good learning process in niche experiments. For this reason there should be attention for underlying assumptions of participants in the experiment (Raven, 2005; van der Laak et al., 2007). Interaction with these participants and learning processes are the main goals, not the protection of a technology itself (Geels and Schot, 2007). Therefore, users in an experiment should not only be seen as consumers with preferences. Such a view on the users has the threat of no depth and breadth in the learning processes because of the low involvement of stakeholders (Schot and Geels, 2008). This means that the way of interacting with users and the way of monitoring, partly influences the learning processes and is thus of the utmost importance.

By interacting with users in an experiment, the users can more effectively articulate their social needs, but at the same time, the provider of the experiment can improve the acceptance and social embedding of the technology (Smits and den Hertog, 2007). Especially when the innovation has a more radical character, a transition process can benefit from close user interaction (Lundvall, 1988).

In the light of strategic niche management, where user interaction and learning are important goals, there should be some kind of selection mechanism for the selection of users in the experiment that can provide feedback. This is needed because not all users are suitable to provide sufficient feedback that will contribute to radical innovations and the transition towards such a technology (Lettl, 2007). Regular market research is therefore not suited in niche experiments in the beginning of a transition. Users that are suited for providing feedback in complex, radical innovations are often referred to as 'lead users' (Von Hippel, 1986). These leading users are on the forefront of a trend, new technology or transition, and their preferences are seen as future preferences of regular consumers. According to Lettl (2007), these creative users are unsatisfied with current technology and are open to new technologies. Preferably they also like to use a product in some kind of extreme context that really tests the new product. In order to have several learning processes, it is important that the providers of the experiment carefully select these users.

The main reason to involve users in innovation processes is the chance of learning. Both the providers of an experiment and the users can learn from the technology and the experiment. This relates to both first-order and second-order learning. First-order learning for users has characteristics of learning by using; getting experience by using products with a high degree of system complexity (Rosenberg, 1982). For users the second-order learning process is about changing their own assumptions and values. This is important because a transition cannot take place without changing entrenched values (Kemp and van Lente, 2011).

Providers of an experiment will also know first- and second-order learning processes. First-order learning for providers relates to the possibilities of a technology. It also consist of new policy options in a given context (Brown et al., 2003; van de Kerkhof and Wieczorek, 2005; Hegger et al., 2007). Providers learn from monitoring the new technology and the users in the experiment. Second-order learning concerns new insights about the problems at hand, the decisions and the context in which problems with the technology take place (van de Kerkhof and Wieczorek, 2005; Hegger et al., 2007) and thus about the assumptions and values that drive stakeholders in the experiment. Second-order learning in experiments eventually helps the providers to implement the new technology into society. In experiments it has to be clear which kind of learning is enabled and whether this is in line with the intended learning outcomes. In experiments there is often the danger of a too large focus on technological learning (Truffer et al., 2002; Verbong et al., 2008).

The role of users in strategic niche management and radical innovation

Users thus have an especially important role to play in strategic niche management; they should be more than sources of market information (Caniels, 2008; Weber et al. 1999). However, a systematic analysis of what type(s) of users can be involved in SNM, and how they should be integrated in the experiment seems to be missing. Several remarks have been made about the incorporation of users in niche experiments, but it is not always clear if these remarks relate specifically to SNM experiments, or to the role of users in innovation processes in general. Weber et al. (1999; 2003) also suggest that user-producer communication should involve lead users. However, lead users should also be representative for the potential adopters, otherwise the innovation may not reach the larger group (Kemp et al., 2001). Weber (2003) states that citizens as users are also useful to be involved. This is often difficult because they don’t have the resources and knowledge, and also lack the incentive to participate. Kemp et al. (2001) state that users should be able to communicate their requirements in order to push suppliers to improve the innovation. Lettl (2007) points to cognitive limitations of users in relation to radical innovation. Users may be fixed to their current use context and not be able to develop radically new ideas; the lack of reference products may hamper their evaluation of the new technology; and the high technical complexity of the innovation may be a barrier for providing valuable feedback. In relation to sustainable innovations, Shove (2003) argues that the involvement of users may even be (partly) counterproductive because their needs and expectations have previously been structured in the socio-technical regime; this influence may be detrimental to the effects that are pursued with the new technology.

Hoogma et al. (2002) found that involvement of users had a strong impact on the satisfaction of the users with the innovation. They state that user involvement is not about getting representative users, or specific groups (e.g. innovators, laggards, etc.), but about creating a platform for a number of users to experiment with new technologies. Rohracher (2003) speaks about involving end-users when a technology is in the transitional period from innovation to the early stage of diffusion. At that stage the technology can still partly be shaped, and there is still openness in the way the technology is adopted by consumers. The different development stages of a technology, may thus warrant the involvement of different types of users.

Special efforts must be made to involve users actively in the experiment on a regular basis, because user involvement does not come about spontaneously (Caniels and Romijn, 2008). Because information of the users is often ‘sticky’, providers of the experiment should have close interaction with the users in order to get access to this sticky information (von Hippel, 1994). Hoogma et al. (2002, p. 191) drew some managerial lessons from a set of niche experiments. They concluded that user involvement was often insufficient: “Users generally played a rather passive role in the experiments. They were hardly listened to, let alone involved in the set-up of the experiment. It was assumed that their needs were known and fixed.”

Why would (potential) users be interested in involvement in experiments? Hoogma et al. (2002, p. 202) name three reasons: 1) to learn about their own consumption patterns and needs; 2) to demonstrate sustainable life styles to others; and 3) to contribute to the reduction of environmental impacts. Lettl (2007) on the other hand describes reasons why users may not be willing to participate: high anticipated switching costs and the fear that their existing knowledge may become obsolete.

3. Methodology

Operationalization and conceptual framework

From the short literature review we derived the main topics for this research. These main topics, which were the basis for the questions in the interviews, are given in the Table on the next page.

Table 1. Dimensions of niche experiments investigated in this study

Dimension	**Descriptive question**
Related to the experiment	
Setup of the experiment	Which criteria were formulated for setting up the experiment?
Selection of users	How were users selected for the experiment?
Expectations of the experiment	What were the expectations of the niche experiment?
Monitoring (of the users)	In what way is the experiment (and the users) monitored?
Learning from the experiment	What learning (goals) have been achieved?
Related to the user(s)	
Commitment of the user	What was done to commit the user to the experiment?
User involvement	What topics were included in the feedback that was asked from the users?
Learning by the users	What first and second order learning could be observed in the users?

The abovementioned topics can be captured in a conceptual framework, which is shown in Fig. 1.

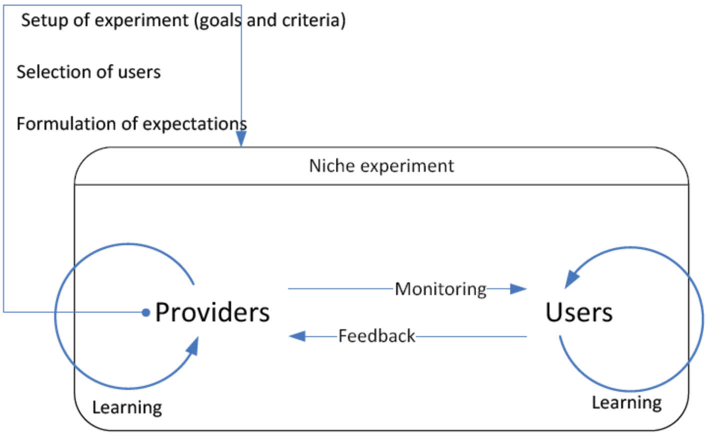

Fig. 1: conceptual model

Case selection and method

Four cases were studied for this paper. One experiment in the city of Rotterdam, one in Den Bosch, an experiment at Rijkswaterstaat[†] and an experiment of Greenwheels, a car sharing company. All four cases were analyzed on the basis of semi-structured interviews with the stakeholders. Thirteen interviews were held with people involved with the provision of the experiments and eight with users

[†] Rijkswaterstaat is the executive body of the Dutch Ministry of Infrastructure and the Environment.

in the experiments. The interviews were coded on the basis of ‘sensitizing concepts’ derived from the conceptual model.

The Rotterdam experiment is one of the biggest experiments in Europe with a total of 75 electric vehicles, and is one of the nine projects within the Dutch ‘electric testing grounds’. Three organizations are involved in the experiment, namely the municipality of Rotterdam, Eneco and Stedin. The results of this case are based on the project plan for the experiment (Project plan Rotterdam, 2009), interviews with two employees from the municipality of Rotterdam, two interviews with employees of energy companies and interviews with three users participating in the project.

This case in the city of Den Bosch is an experiment with a pooling system in cooperation with several companies near the ‘Paleiskwartier’ area, together with the municipality of Den Bosch. The companies involved have 11 electric vehicles at their disposal. The results of this case are based on the project plan for the experiment (Project plan Paleiskwartier, 2010), four interviews with actors involved in the project and two interviews with users.

The experiment within Rijkswaterstaat is an experiment with 24 electric vehicles. With a total of 1750 cars in their fleet, the Dutch government chose Rijkswaterstaat for this experiment because of their capacity to ‘back up’ electric vehicles with conventional cars when necessary. The results of this case are based on the project plan for the experiment (Project plan RWS, 2010) and three interviews with providers of the experiment. Three interviews were conducted with users involved in this experiment.

The experiment of Greenwheels is the only experiment in this research where a commercial party has a leading role and where basically every Dutch citizen with a driver license can make use of electric vehicles. Greenwheels is a car sharing company where people can rent a car, minutes before they need it, and pay per kilometer and the time used. In this experiment, 25 of these Greenwheels cars, which can be found in every bigger city in the Netherlands, were replaced by electric Peugeot iOn’s. These characteristics make the project a rather unique project. The results of this case are based on the project plan for the experiment (Project plan Greenwheels, 2009), three interviews with providers of the experiment. We did not get permission to interview the users (customers) in this experiment. However, we could see the results of the user survey (Greenwheels, 2012), filled in by 147 of the 320 users of the electric vehicles in the experiment.

4. Results

The Rotterdam experiment

Three partners were involved in the Rotterdam experiment, each with slightly different goals. In order to achieve these goals, the organizations formulated some criteria for the experiment. However, the criteria for the subsidy from the Dutch government played an important role in the setup of the experiment. The original idea of decentralized generation was not incorporated in the experiment because this was not allowed in the subsidy scheme. The parties involved wanted to be able to compare between cars and to have enough data for statistical analyses. Of the 75 cars in the project, 30 are converted cars from the firm AGV, which was declared bankrupt in November 2011. Extra costs and a lack of service for the converted cars was the result.

All three parties involved had their own selection mechanisms of the users in the experiment. The city of Rotterdam simply looked at the expiring lease contracts within their car fleet. Within this group, a talk with the manager would clarify if the user of that car was a good option for an electric vehicle. At Stedin, employees who were eligible for driving an electric car should be motivated to participate and have the availability to charge at their home. Because few users met these criteria, a lot of electric vehicles were made part of a pooling system. Most potential users were not very enthusiastic in the beginning about getting an electric vehicle. They did not like the idea to be monitored in every move they made with the car. Eneco selected all mechanics that drove less than 100 km a day. Next to this, the managers of different departments would then select the most enthusiastic drivers for an electric car.

In order to monitor the users they have to fill in a survey every quarter of a year. All users also have a logbook in the car to fill in experiences during their driving. Information from the logbook should be emailed to the organization, but according to the interview with Eneco this is often forgotten by the users. Therefore the users are called to tell about the information in the logbook. In order to communicate outcomes towards the users, a website was constructed. Within a few weeks the first results should be published on this website where some users are registered. Only the users that have a car for personal use seem to be registered on the website. The website is meant to share experiences between the users and also to communicate the outcomes. In February 2012, an event was organized for all users in order to communicate the goals of the project, to give the possibility to ask questions and to share expectations.

All interviewees seem to agree on the fact that the enthusiasm of the project team affects the enthusiasm of the users in the experiment. This makes the task of a project team more than only the monitoring of the experiment; they also have to motivate the users according to the interview with Stedin. At the municipality of Rotterdam, the interviewees felt that in future experiments a closer interaction with the users would be preferable, but they expected that that would also be difficult to arrange.

The three interviewed users in the experiment all have an electric car for their working activities; they use their electric vehicle on a daily basis. In all cases their direct boss imposed the electric car on them. One user did not like this and the other two users accepted it. They stated that little information was given beforehand about the project. The users did get a short introduction on how the car was started, how the charging worked and how the payment system worked. The information day in February 2012 was to most a nice day and to one interviewee a day with not enough space for users to participate and too little information about the technology and charging. The information about the charging infrastructure is poor according to the interviewees. Most of them only charge the car at the office, but it is difficult to find out in what other places the car can be charged.

According to the users there is no special attention for them in the experiment. Most of the communication is with their manager; two of the three users where called about the experiences with electric driving. The other user got a survey sent by e-mail. One user gave some information about his troubles with the car at the user meeting in February but missed questions in the survey about these topics. In the interview, this user explained his feelings about being thrown into the deep end. The other two users that were interviewed felt less negative about the experiment. Both users accepted the fact they had to drive in an electric car. One of them received feedback by e-mail about a telephone interview he had had, the other did not.

All users explain that the problems with electric driving did not diminish, but that they got used to the troubles. They learned to plan their trips and learned to judge under what circumstances the car performs best. One of the users thinks about buying an electric car for personal use, but only if the cars will have the same price as regular cars and will have an increased range. The second user expects to drive the electric car for his work in the next years because he works at a sustainable and 'green' company. The third user hopes to get a conventional car in the future.

The experiment in Den Bosch

Brabant Water, one of the participating companies in the experiment, took the lead for the experiment. The interviewee explained the choice for a pooling experiment. The company already had a pooling fleet where most cars drove short distances that would perfectly fit for electric vehicles. Besides, some of the conventional cars needed to be replaced and the replacement by electric cars could partly be subsidized. Therefore, subsidy criteria were also quite important for this experiment.

All interviewees confirmed the focus on the viability of a future business case for electric driving in a car sharing concept. Because of the novelty of the technology, little was known about electric driving beforehand. The learning goals were different for the stakeholders involved. The municipality is especially interested in questions about parking. Free parking spots for electric vehicles at a charging spot have a negative influence on the cash flow from parking fees for the municipality.

No criteria were formulated for selection of the users within the project team. A central booking system for all companies is the only centrally decided agreement with regard to the users. According to the interview with Prolease the original idea was to start small and get the teething problems out of the way before a large group could make use of the cars. In the interviews with the participating organizations Brabant Water and Avans, it was evident that both organizations had no strict selection criteria for the potential users in the experiment. Avans chose to send an e-mail to all 600 employees in one office to alert them about the experiment. 20 employees chose to participate. Brabant Water chose to promote the electric vehicles actively amongst the departments with the highest use of the conventional pooling fleet. Within these departments, Brabant Water tried to select the most positive people in order to prevent negative association with the concept of electric driving in the company.

In all the interviews the focus on technical learning was emphasized. Measuring instruments are built in the electric cars to measure the energy flows in the car. According to the interview with Brabant Water the charging time, energy use per kilometer and the overall energy use are measured. None of the companies have a regular survey or other information channel for their users with which they can share their experiences. According to the interview with Brabant Water, such a survey is not needed because problems with the car find their way to the project team anyway. The interview with Prolease revealed that besides the technical information from their measuring instruments, the users contacted Prolease when having problems. Because Prolease is leasing the cars, the users contact Prolease in cases of empty batteries or other problems with the car. Prolease encounters that users that call for problems tell more about their experiences next to their complaints about problems they had.

According to all interviewees, the start of the experiment had some technical difficulties which forced them to focus on these problems instead of focusing on the users. Now that these small problems have been managed, the focus is still on the technical aspects of the experiment. In the beginning of the interview, students of Avans Hogeschool monitored a part of the experiment and presented this for the project team. Main conclusions according to the interview with Avans were that the project should be easier and more reliable for the users. This led towards an easier booking system.

Especially in the beginning of the experiment there were many technical problems with the monitoring system. Because of these problems the experiment was not very much promoted amongst employees of the companies which led to little use of the electric vehicles. Next to the technical learning, all interviewees acknowledge the importance of users. Negative experiences of users are quickly spread, according to the interviews. People were often not that willing to be flexible with a new technology but need to change their behavior for an experiment like this.

Both users in this experiment were not involved in the experiment from the start. When one user heard the electric vehicles were barely used in the experiment, he asked for permission to use one electric car for personal car pooling use with his colleague. This was approved of by the project leader. The interviewee from Brabant Water wanted to experience electrical driving and wanted to contribute to sustainability. The interviewee from Avans had the same reasons as his original carpooling reasons. It is more fun to drive with a colleague to work, it is better for the environment and it saves costs.

The interviews with the providers of this experiment indicated that there is no structural feedback mechanism for the users in the experiment. Every party involved is responsible for their own users. This is reflected in the interviews with the users. Problems with the electric vehicles or experiences are often shared with the car fleet manager but it is not clear whether the fleet manager communicates these experiences to the project team. The user from Avans was aware of three different feedback moments of which he attended two. There was one lunch, one telephone survey and one survey by e-mail. According to this interviewee it is difficult to give feedback because everyone has different experiences. At least the different feedback moments showed, according to the interviewee, that Avans is trying to get all the information form their users. No feedback is, however, given on the input from the users.

Both users indicated they like to drive electric cars in the experiment. Although there are troubles with the booking system, the interviewee from Avans indicated the problems are decreasing. Especially because the first time is always more challenging than the twentieth time you do something. The interviewee from Brabant Water also acknowledges the learning curve he is going through as a user. The user from Brabant Water also thinks more could be learned for both users and providers of the experiment if users are allowed to make personal use of the car and not only in a pool experiment.

Experiment at Rijkswaterstaat

Several parties and ministries of the Dutch government were involved in formulating the project at Rijkswaterstaat (RWS); this led to different goals and mindsets. Some focused on sustainability, while others focused on the costs. An external party, Ecofys, formulated the goals and intended learning outcomes for the project but had to deal with political interference. With regard to the goals of the experiment the interviewees named two overarching goals. First of all, RWS wanted to find the best way to integrate electric vehicles into their car fleet. The second goal was to find out in what way electric vehicles would fit into the business of RWS. There were several reasons for an experiment with electric driving at RWS. Firstly, the size of the car fleet was perfect because they have ample conventional back up cars. Secondly, RWS recognizes the importance of CO_2 reduction and thirdly, RWS wanted to practice what they preached about sustainability and the future for electric driving.

It was important that the users involved in the experiment would participate voluntarily, and were not forced to make use of EV. With the availability of a backup car it was easier to see under what circumstances people would choose for the electric car and under what circumstances they would prefer a conventional car. To get an even better insight in the usage of electric vehicles, three types of usage were involved in the experiment. Some cars were assigned to one user, who can use the car for commuting and for his or her work. Other cars were part of a pooling fleet and can be booked by a large group of people. The third type of usage is as a car for the field service. In that case the car is assigned to a small group of people that use the car only for work purposes. According to the interview with TNO, the development of these criteria was not a very structured process.

The project team wanted to select users that participated voluntarily and who were enthusiastic, but they didn't always succeed. In some cases, people were personally asked because it was well known they were interested in electric driving. In other cases, departments were asked for involvement of some interested users. However, the decision was also made for a specific department that they should cooperate in the experiment. The 'involuntarily' involved departments were also the departments where the electric vehicles were hardly used. Besides the intention to select enthusiastic users, there was no special selection procedure for the users. In the cases where departments could not find enthusiastic users, the experiment is not a big success. People at those offices are afraid to drive in the electric vehicles because they have no idea how they work and what the range is of a charged battery. TNO organized a meeting for all the interested departments about the goals of the experiment and about electric driving in general. This event was well attended by the interested departments, but probably not by the departments that were not interested but still had been given an electric vehicle.

There are three ways of gathering information in this experiment. First of all there is a black box in every car that measures, for instance, the energy use in the car and the distance driven on one battery. There is, however, no track and trace in the cars and also no measuring of the life cycle of the battery. Secondly, all users get a survey every quarter of a year with 17 questions about safety, driving experience, charging and usage of the car on a ten point scale. In principle, the users get this survey before they use the car, and a few months later when they stop using the car. This helps to make the difference between expectations and experience explicit. The surveys were adjusted on the basis of the first completed surveys and other monitoring information. Before the experiment, there was an interview round with potential users and at the end of the experiment there will be a concluding interview round if possible. Thirdly, all the information about maintenance and damage is monitored. The electric vehicles in this experiment are not as much used as expected. Because of the low usage, the costs per km are relatively high which gives an unnecessary negative idea about the costs of electric driving.

All three users indicated that there was a lot of information given about the experiment. There is a book in the car with information about the car and about charging, and some even got a small instruction about the car. One user was asked to be ambassador for his department because of his enthusiasm for electric driving. They organized a meeting for the 130 people working at that office, of which 15 people came to hear about the project, its goals and to drive in the car. Eventually, all 15 participated in the project. All users experienced that they had been given sufficient information beforehand. The reasons to participate were very diverse. One person wanted to participate because he wants to stimulate electric driving from a sustainability perspective and because he is in charge of a pool system. Another participant did not want to know anything about sustainability because there is not enough information for a single user to state that EV is better for the environment. She participated because an electric car seemed to be perfect for her responsibilities within RWS. The third interviewee calls himself a real ‘petrol head’ and monitors everything around cars. He really likes the innovative character of the experiment and to be an early adopter of a new technology. The freedom in the usage of the car within the experiment is therefore really good according to him. All users were involved because they showed interest in some way in the experiment with electric driving.

All the users filled in the survey several times. The survey was sent before the first drive, during the participation in the experiment and at the end of the quarter of a year, when officially the car should change to another user. The questions in the survey were about the whole driving experience and performance. The survey also has space for some comments. However, the space for comments is too limited according to most users. It is hard to inform the project providers with your experiences when the battery fails or when other problems occur. For instance, it is known that not all electric vehicles are used in the experiment, because at some departments, people are afraid to use the car. Emotions are of such an importance with new technologies, that there should be more focus on these emotions in the monitoring. According to one user, it makes sense that there are problems with such a new technology, but by qualitatively asking the users a lot of information would come up faster than is the case now. With more qualitative research within the experiment, more would have been learned with regard to user preferences and emotions you’re dealing with when experiencing this new technology. It is understandable that quantitative surveys are easier to conduct, but emotions behind experiences cannot be caught on a Likert scale.

Problems with the range of the car and an unclear overview of the charging facilities in the Netherlands can be written down in the survey. Feedback on the car, the use of the charging cable and other ‘hardware’ is more difficult, because there are no questions about these topics. Overall, experiencing electric driving and experimenting with the range and other aspects are both fun and sometimes hard to do. For the users it is hard to see what happens with their responses in the survey. They are also curious about the experiences of other participants. There might be more value in the experiment when user experiences could be shared with each other. Still, all participants mentioned it to be great to have a role in such an experiment with a technology at the start of its development. It is experienced to be both fun and difficult to make colleagues enthusiastic and to make use of the electric car in different situations.

Experiment at the car sharing company Greenwheels

To start, electric vehicles seem to be perfect for car sharing concepts. Not only the interviewee from Greenwheels indicated this in the interview, but interviews with people from other projects also see a future for electric vehicles in a car sharing concept. Most of the criteria for this experiment were dictated by the subsidy criteria, according to the interviewees. There were however some demands from the participating parties. Greenwheels wanted to communicate the electric vehicles to be ‘normal’ cars; so they chose not to have some special marketing strategy for the electric vehicles. The interviewee from the municipalities indicated that all cities had their own demands. Den Haag for instance did not want extra parking spots for Greenwheels in the city while Amsterdam did not want charging spots from another energy company than Nuon. Because Essent was one of the project partners this at first was a problem.

According to the interview with Greenwheels the goal for them was to find a business case. Electric vehicles in a car sharing concept sounds well, but as a commercial party they wanted to find out in what way and with what costs a viable business case could be found. The interviewee from the municipalities indicated that the placement of the charging spots was the most interesting goal of the experiment. Different definitions between cities about these spots led to different approaches. Eventually all cities cooperated, but the different definitions and procedures were time consuming. All interviewees also emphasized that the reaction of the public was an important goal. Not only reactions from users are important, but also the reactions of local residents near charging spots. Something all interviewees highlighted as positive was the signing of a contract with all the goals and responsibilities for all parties. In this way everyone was aware of the goals of the project and was committed to the project.

The selection of the users was not a big issue in this experiment. According to the interview with Greenwheels they made the deliberate decision to make the electric cars accessible for all Greenwheels members. At the time of the start of the project there were some negative rumors about electric driving and Greenwheels wanted to show with this experiment that electric cars are easy to use and accessible for everyone. Every electric car has a check list about driving the car, just like the other cars of Greenwheels only adapted for the electric car. This proved to be enough for customers to use the electric cars at the opening event of the first electric car.

Monitoring

The technical monitoring is done by Greenwheels because they have the information by installing the monitoring hardware in every car, just as they do for their conventional cars. Monitoring in the charging spots is done by Essent. Most of the information from these monitoring is already known. In the case of specific questions, results of the monitoring instruments at the charging spots are always available. According to the interviewee from the municipalities the user monitoring is less interesting because most things are already known; people feel that the range is too low, the low noise level is great and it is good for the environment. Most interesting about the users is the range they dare to drive and when they use an electric car. The interview with Greenwheels indicated a survey for the users is sent every six months by e-mail. Results from these surveys are discussed in the project team and first results showed that many problems of the users are based on perception. This challenges the project team to deal with these problems in a different way. All interviewees indicated a survey with local residents around charging spots should be done in the upcoming months to provide insight in the way they feel about charging spots in their district.

All interviewees indicated that much had already been learned in the experiment. The interviewee from the municipalities felt that the municipalities had learned the most in the early stage of the experiment, about the placement process of the charging spots. The knowledge about the placement of charging spots is really helpful and is paying off already in other projects. The interviewee from Greenwheels indicated that much was learned about the business case and that there is no attractive business case right now. The extra costs for electric driving, like the price of the car and vandalism at charging spots, cannot be recouped in some way for the company, but they do get a lot of positive reactions from the public. Thereby he agreed that a lot is learned about procedures. The choice for dealing with the electric car as a 'normal' car was, in hindsight, not the best decision.

No interviews were conducted with users in the Greenwheels experiment, but the results of the first survey amongst the users were provided by Greenwheels for this research. The regular customers of Greenwheels are, according to the survey, highly educated, are 43 years in average and the male/female ratio is evenly distributed. Based on a 46% response rate in the survey of Greenwheels, 80% of the electric car users in the experiment are male in the age category between 31 and 54 years old and with a high education. Most of the respondents (85%) had their first electric drive with the Peugeot iOn in the Greenwheels experiment and 60% of them prepared this first drive by visiting the website of Greenwheels or reading the instruction book in the car. Most people had a positive expectation about electric driving and for most of the users the real experience exceeded these expectations. Despite the expectation of the project team that the range of electric cars in a car sharing concept is sufficient, 48% of the users indicated that the range is not sufficient and 51% indicated they felt the fear of suddenly having an empty battery. More charging spots would also be nice according to the respondents. The other experiences with driving the electric car were positive, like the low noise of the car, the driving experience and the safe feeling in the car. When having to choose between driving in the city, outside the city and on the highway, the electric vehicle is best rated when driving in the city. Charging the car takes too long according to the respondents. When asked if people would recommend the electric car to others on a ten point scale the average score is a 7.5. For 65% of the users, the availability of electric cars is an extra reason to drive with Greenwheels. And if asked to rate electrical driving with Greenwheels on a ten point scale the average score is a 7.1. When the car is booked, it is not known how long the car can be used and since the charging time is quite long, users experience this as annoying according to the comments. Overall, the comments hint at more communication about the small range in bad weather and information about charging spots and charging time.

5. Analysis

The setup of the experiment

According to the literature, the set-up of an experiment is important. The environment and thus the criteria of the experiment should be in line with the goals of the experiment to make sure what mechanisms of the new technology are tested (Kemp et al., 1998). In that sense, each goal should be reflected in the criteria for the experiment. Similarities between the different cases are that for all cases the subsidy criteria played an important role. The project in Rotterdam for instance wanted to incorporate a smart grid experiment in the electric vehicle experiment. Because this was not allowed in the subsidy conditions this idea was abandoned. All cases acknowledged such a big influence of the subsidy criteria on the establishment of their project. An exception in this respect is the case of Rijkswaterstaat. They chose to let an external party, Ecofys, formulate the goals and criteria. The project plan of Rijkswaterstaat therefore clearly shows in what way the criteria of the experiment are based on the goals. The alignment between the goals and the criteria of the experiment should however at least be optimized by the project team of an experiment. In that respect, the Rijkswaterstaat project was the only case with a clear alignment between the goals and the criteria of the experiment. In the other cases, the link between the goals and criteria was less clear.

Next to the alignment between the goals and criteria of the experiment, an open and shared vision is important in the experiment (Raven, 2006). Greenwheels is the only experiment in this research that indicated to have written down the goals and responsibilities of all involved organizations and let them sign for it. The other experiments did mention some agreements amongst the parties involved but also acknowledge the freedom for own goals and the unawareness of the specific goals of other involved organizations. While freedom for every involved partner to choose their own goals is important, these differences should be made clear and accepted by all partners (Kemp and Loorbach, 2006; van der Laak et al., 2007). This is what did not happen in three of the four cases in this research. Only Greenwheels managed to make differences and goals explicit for the project partners. This does not necessarily mean that the vision in the other projects was not shared. However, because of the unawareness of the differences between the project partners and implicit differences in these projects, the vision seemed to be less aligned than in the case of Greenwheels.

User selection

Users encounter the problems with electric driving during the experiment and should communicate this towards the project team. Because not all users can play such a role, users should be selected for their openness towards new technologies, their enthusiasm and possible use of the technology in an extreme context (Lettl, 2007). It was striking that in almost all experiments there was no real selection of users. Expiring lease contracts, or a strategically chosen location were important criteria for the placement of electric cars. Next to this, in two cases enthusiastic users were sought, but this proved to be hard because of the reservations of employees towards new technologies. In Den Bosch the companies practically gave all their employees the possibility to make use of the cars, which automatically led to a reaction of the most enthusiastic users. Greenwheels gave all their customers the possibility of using the electric cars because they wanted to communicate the car as a 'normal' car. This shows that the selection of the users was not the most important part in setting up the experiments. It also proved to be difficult for the project teams to select the right users for their experiment. There were not enough users that indicated to be enthusiastic in joining the experiment.

Another important aspect is the relationship with the users in the experiment. This relationship should be stable and intense according to the literature in order to transfer specific knowledge of the users (Madhavan and Grover, 1998; Mascitelli, 2000). In practice, this proved to be difficult. In advance, none of the experiments in this research composed some kind of communication protocol for an intense relationship with the users. All of the experiments tried to improve the communication with the users after the start of the experiment, or is planning to do so. Rotterdam organized a user information day, but still the providers indicated that a smaller experiment and a more intense relationship with the user would improve the experiment. Rijkswaterstaat indicated that an ambassador at every department, or the selection of departments with enthusiastic users would have improved the experiment. In the case of Den Bosch a better communication with possible users was a point of improvement and in the case of Greenwheels also better communication was put forward in the interviews.

Monitoring

Good experiments differ from bad experiments with their anticipation on unexpected problems. Such a good anticipation is necessary to prevent the experiment for having a low quality of learning in the experiment (Verbong et al., 2008). All experiments under investigation had their problems and started later than planned. Rotterdam had troubles with the bankruptcy of AVG, the party that converted conventional cars into electric cars. This led to problems with users that drove these cars. Rijkswaterstaat had troubles with the delivery of the electric vehicles.

There is no real feedback mechanism with the users about the project or the outcome of surveys. Den Bosch is really focused on technical learning and not on the users. There is technical monitoring in the Greenwheels experiment, but also regular surveys amongst the users and planned interviews with local residents. This seems to be a good mix of information channels.

All experiments started with three kinds of monitoring. Often, there are measuring instruments in the car and in the charging spot, monitoring of the users and finally monitoring of problems with the cars. The experiments do have a different focus in the monitoring. However, most of the experiments have some kind of focus on the technical aspects of electric driving. This focus is on the energy flows, the technology in the car or the charging infrastructure. Greenwheels is the only experiment, based on the interviews that really tried to incorporate both users and local residents in the experiment. This is a missed opportunity for the other experiments since they focus less on the incorporation of the users in their project.

Learning from the experiment

All interviewees from all experiments indicated they learned a lot about electric vehicles and from setting up the experiment. Most of the projects got, with their first results, some insight in a possible business case. However, they all learned in some way or another that users should be involved more in the experiment. The Rotterdam experiment wants closer interaction with their users in the future but is not quite sure in which way this should be organized. A user event, like the one organized in February 2012, is likely to be repeated in the near future. The Rijkswaterstaat experiment experiences a too low usage of the electric vehicles. According to the interviewees the back up by a conventional car is debit to this. Closer interaction with the users is expected to raise the usage of the vehicles. The Den Bosch experiment experienced that negative experiences of users after technical problems are hard to transform. Finally, in the Greenwheels case, the project team learned that the users wanted closer communication about the technology and the availability of charging spots. This shows the focus is not on the users because the information about the technology and charging spots is available, but not communicated towards the users. It shows the focus on technological learning in the experiments, of which the literature warns. Especially in experiments were there is a possibility of learning in multiple dimensions like the societal fit of the technology there is a danger of focusing on the technology (Hoogma et al., 2002). The focus is mainly on first-order learning processes which could by widened with second-order learning processes by for instance closer interaction with users in order to learn from user preferences as well.

Commitment of the users

Users should feel committed to the experiment in order to let them formulate their social needs (Smits and den Hertog, 2007). All users had information about electric driving and most of the users in the different experiments rated this information as sufficient. Some felt like being thrown into the deep end, while others would have liked to have had some kind of electric driving course. But overall, the information beforehand was not a real problem to most users.

It is easier to feel committed to something one voluntarily joined than something one was forced to do. In that sense it is not a good thing that some users were ‘forced’ to participate. As was described in the paragraph user selection, the expiring of lease contracts sometimes was a reason to give someone an electric car. Such a way of selecting users is not ideal to commit users. A lot of users also voluntarily joined the experiments, but had the most divergent reasons: from sustainability, costs, curiosity and accessibility. All were arguments to participate. Some of the users were enthusiastic and others accepted their role but did not show commitment to the experiment. In general, the users that voluntarily joined felt, unsurprisingly, more committed to the different projects than the ones that did not spontaneously join a project. There seems to be a role for the providers of experiments to find the willing users and to commit them to their project.

User involvement

Close involvement with users is important for a project team in order to distract the 'sticky' knowledge of the users (von Hippel, 1994). This implies more activities should take place than just user surveys to capture users experiences, since a survey is not the best method to obtain sticky information (Lettl, 2007). Almost all users have filled in one or more surveys about electrical driving in their experiment. Overall, the users in the experiments missed open questions about problems with the electric cars; most of them accepted this as a fact. But as one of the users mentioned, "it is hard to rate emotions about electric driving on a Likert scale". Almost all users had some negative or unexpected experiences with electric driving, but most of the project teams missed this information, or at least failed to obtain this kind of information in a formal way. Almost all users indicated they wanted to give more information to the project, or they wanted to share experiences with others. A user event for each experiment was raised as an option by some users in order to have the possibility to share experiences with each other and to give each other tips. The project teams, however, focused on surveys in order to obtain user information instead of other possibilities. In Rotterdam there had been a user event, but this event was more focused on giving information to the users than on getting information from the users.

In none of the experiments did all users get feedback on their input given in the surveys. Interaction with users implies information streams in two directions. Without feedback it is hard for users to see what happens with their input, which may decrease enthusiasm by the users. At least the interviewed users indicated they would like to know what happens with their information and if other users experience the same problems.

Learning

Problems with the range of the electric vehicles and the long charging time are problems that will probably last for a couple more years. All users however indicated that they got better in estimating the distance that can be driven with one charged battery. They got used to the silence of the car and the possible danger for pedestrians. The differences with conventional cars are clear and are mainly linked to the range of the car and the long charging time. All the users that drove a Nissan Leaf indicated that this car can really compete with conventional cars, besides the range. Other cars are often associated with too little power, and a feel of unsafety because they are too small. How and what they exactly learned was often difficult to communicate to the project team of an experiment, but almost all users indicated they like to drive in an electric car once they were used to the restraints of such a car.

6. Conclusions and recommendations

In this research we found that setting up an experiment with clear goals and matching criteria can be difficult. One reason is that criteria from subsidy schemes have to be taken into account. Another mechanism that we observed is that several parties in an experiment all have their own goals and criteria, but do not adequately communicate these goals within the project consortium.

In the cases that we studied, we found that users for the experiments with electric vehicles were often not specifically selected for this task. The users involved were usually employees of the companies executing the experiment or customers of the company executing the experiment. The providers of the experiment almost all had difficulties with selecting users and with the interaction with their users. When the enthusiasm of the users is a criterion, it becomes more difficult to find enough users for the experiments.

Furthermore, the providers of experiments had troubles in extracting the learning experiences from the users because of a too distant relation with these users. They did learn a lot about the electric vehicle and the difficulties of setting up an experiment, but the needs of the users and their experiences with the electric car were often not a focus in the monitoring process. At the same time, the users indicated that they have ideas about how the experiment could be improved. A small part of the users also got insight in their own assumptions about electric vehicles, enabling second-order learning. In the few cases of second-order learning by the users, the providers of the experiments were not able to extract these lessons.

Despite the important role that users should play in experiments in the early stage of a transition, we found that there are difficulties in selecting and interacting with these users. The interaction is generally one way traffic, since project teams wanted users to fill in a survey but did not discuss the outcomes of these surveys. Literature indicates that a close relationship with the users in experiments is important for the quality of learning in the experiment. This research shows the practical difficulties for providers of experiments to set up this interaction for a good learning experience.

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Submission 143

Extending Transition Management: A second-generation meta-governance framework

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Abstract

It is widely recognised that sustainability challenges in climate, energy, transport and water contexts mean radical changes in the design and management of socio-technical systems are urgently required. Transition management was developed as a meta-governance framework to address these challenges, focused on governing towards long-term sustainability goals by stimulating new innovations through a reflexive adaptive process. However, it has two limitations in its current form. First, it does not have explicit mechanisms to conceptually link governance processes with analytic insights about transition dynamics. Second, the instruments and methods used in transition management are directed at the pre-development stage of a transition and is therefore limited in its application at the take-off, acceleration and stabilisation stages. This paper aims to extend transition management to address these critical gaps by proposing an architecture of a second generation meta-governance framework for transformative change. The framework is designed to translate conceptual understandings of transition dynamics and reflexive forms of governance into a prescriptive model for application in specific transition contexts during all stages of a transition. The framework architecture is based on an iterative six-phase cycle that comprises specific process and content goals, with content and learning flows between phases. Different content and process tools are required to deliver the goals for each phase, constituting a toolkit that accompanies the meta-governance framework; existing transition tools fit one or more phases. The proposed framework provides an overarching logic for coordinating research focus and outcomes in the development of the next generation of transition management initiatives.

Key words
diagnostic procedure; governance; meta-governance framework; sustainability transitions; transition management

1. Introduction

Sustainability challenges are well explored in literature from diverse research fields and in many contexts, such as climate, energy, transport and water. The common message is that scholars and practitioners recognise radical changes in the design and management of socio-technical systems are urgently required (Grin et al., 2010; Chapin III et al., 2009). Despite robust debate within the literature on whether active navigation of a transition is desirable or possible (see, for example, Genus and Coles, 2008; Shove and Walker, 2007; Smith and Stirling, 2010), there is a growing community of academics, planners, policy analysts and decision-makers interested in making explicit interventions targeted at enabling sustainability transitions. While desired technological and/or procedural practices have been identified and tested for many socio-technical systems, there is limited understanding of how to intervene effectively in particular implementation contexts to enable the broader societal transitions for supporting new innovative solutions (Chapin III et al., 2009, Grin et al., 2010; Westley et al., 2011).

Transition management was recently developed as a meta-governance approach in the absence of prescriptive guidance for enabling transformative change (Loorbach, 2007; Loorbach, 2010; Voβ et al., 2009). This is a novel framework, focused on achieving long-term sustainability goals by stimulating new innovations through a reflexive adaptive process (Loorbach, 2010). As the first proposed framework of its type, it has attracted strong interest within transitions and governance scholarship. While there is contention around its empirical validity, effectiveness and engagement with power, politics and agency (Grin et al., 2011; Grin, 2012; (Loorbach and Rotmans, 2010; Rotmans and Kemp, 2008; Shove and Walker, 2007; Voβ et al., 2009), transition management has made a significant contribution to academic debate on governing long-term change for more sustainable outcomes. Policy practices in Europe and beyond have also been influenced, with a wide range of transition experiments and innovation programs established through the facilitation of transition management processes. Empirical testing of transition management in different policy arenas is ongoing (Loorbach & Rotmans, 2010; Nevens et al., 2013); however, there are two critical limitations in its current form.

First, transition management does not have explicit mechanisms to conceptually link governance processes with analytic insights about transition dynamics. Research within the field of sustainability transitions has sought to explain the patterns and trajectories of transformative change with increasingly sophisticated concepts and models (e.g. Rip and Kemp, 1998; Rotmans et al., 2001; Geels and Schot, 2007; de Haan and Rotmans, 2011). As such, there is significant potential for diagnostic insights about a socio-technical system's dynamics and transformative capacity (based on transition concepts) to inform the selection and design of strategic initiatives. Instead, transition management largely relies on the tacit knowledge of actors elicited through process instruments, to identify and prioritise strategies for enabling a transition (Loorbach, 2010; Nevens et al., in press). While tacit knowledge is valuable, theoretical knowledge about transition dynamics, developed through diagnosis of a wide range of cases, would significantly improve the basis for strategy selection and design in local system contexts.

Second, the instruments and methods used in transition management are directed at the pre-development stage of a transition (Loorbach, 2010; Loorbach and Rotmans, 2010). It is therefore limited in its application beyond the initial stimulation of niches and does not have the capacity to guide engagement with regime actors for mainstreaming innovations (Grin, 2012). Most transitions, particularly in urban infrastructure systems, are unlikely to involve complete substitution of a new technology. In urban water, for example, the regime of centralised water supply infrastructure provides a highly valuable role for society in equitably delivering safe, clean and secure supplies of drinking water across a city. System transformation needs to occur, but the regime must be engaged in that transition, particularly in its later stages. While stimulation and incubation of innovations are important and may be best undertaken outside of the regime, the take-off, acceleration and eventual institutionalisation of those niches with mainstream will require different governance processes and engagement with a much broader range of actors.

Empirical observation of transition management processes, as well as the related fields of strategic niche management and adaptive management, highlights strategic features that have been critical for enabling successful transitions. For example, sharing a common vision (e.g. Loorbach and Rotmans, 2010; Voβ et al., 2009), technical and governance experimentation (e.g. Farrelly and Brown, 2011; Huitema et al., 2009); incubation of innovation (e.g. Westley et al., 2011); stimulation of social learning (e.g. Bos et al., 2013; Pahl-Wostl et al., 2007); shadow networks (e.g. Olsson et al., 2006); nurturing of leadership (e.g. Huitema and Meijerink, 2010; Olsson et al., 2006); and creation of bridging organisations (e.g. Berkes, 2009; Folke et al., 2005). However, there is limited scholarly guidance on how and when these different initiatives should be utilised to most effectively influence the speed and direction of a transition. Development of a logic for coordinating different types of strategic interventions throughout a transition is a critical next step in the scholarly and practical extension of transitions governance concepts.

In summary, the transition management framework needs extension if it is to be capable of critically informing the selection and design of strategic initiatives to most effectively influence each stage of a transition. Key research questions for developing transition management in this direction include: How can diagnostic insights about transition dynamics inform governance interventions for transformative change? How should a governance framework be designed so it is applicable for all stages of a transition? What strategic initiatives are most effective for different transition stages? How can existing transition tools be best utilised to support strategic initiatives?

This paper aims to provide a starting point for systematically and critically engaging with these research questions by proposing an architecture of a meta-governance framework as a scholarly basis for developing practical strategic guidance. The framework aims to translate conceptual understandings of transition dynamics and reflexive forms of governance into a prescriptive model for application in specific transition contexts and provides operational guidance for actors wanting to steer system-wide transitions. The proposed framework provides direction for transitions scholars to develop the second generation of transition management with an overarching logic for coordinating research focus and outcomes.

2. Developing the Framework

The approach for developing a second-generation transition management framework, that addresses the critical gaps identified above, involved meta-analysis of scientific literature and an empirical case study of a successful practice transition in the urban water system of Melbourne, Australia. This research was undertaken through a doctoral program and the current paper represents the overall contribution from that work.

Details of the methods for individual components of the research are documented in separate publications. Ferguson et al. (2013) reviews existing frameworks in scientific literature on transformative change to assess their potential for contributing to diagnostic assessments; Ferguson et al. (submitted a) proposes a diagnostic procedure based on theoretical concepts from transitions, resilience and institutional scholarship; Ferguson et al. (submitted b) proposes a strategic program for transformative change in urban water systems drawing on lessons gained through a transition scenario development process implemented in Melbourne.

Results across these individual studies were triangulated to inform the design of a scope, architecture and toolkit for the proposed meta-governance framework. The following section presents these findings.

3. Presenting the Framework

The proposed second generation meta-governance framework for transition management is explicitly normative in its application, underpinned by the long-term goal of achieving a desired future system. The framework aims to translate conceptual understandings of transition dynamics and reflexive forms of governance into a prescriptive model that can provide operational guidance to actors wanting to facilitate transformative change in a system.

3.1. Framework Scope

Meta-analysis of literature on transitions and governance guided scoping of the proposed meta-governance framework. While space limitations mean full explication of individual results from this research cannot be detailed here, key outcomes are presented to demonstrate how they informed the design of the meta-governance framework.

Literature on the dynamics and governance of transformative change identifies key principles underpinning the design of a governance framework for guiding transformative change (e.g. Chapin III et al., 2009; Grin et al., 2010). The tenets of transition management proposed by Loorbach (2010) integrate many of these principles:

- Content and process go hand-in-hand
- Short-term goals are based on long-term thinking
- Objectives are flexible and adaptable, rather than formulated with a blueprint approach
- The timing of interventions has explicit consideration
- Periods of chaos and disruption bring opportunities for effective interventions
- Innovation is fostered in spaces protected from competition with existing regimes
- Internal and external factors influence system change
- Social learning is critical for facilitating transformative change
- Policy development and social learning are facilitated in participatory settings.

These tenets, as the foundation of transition management, form the overall scope of the proposed meta-governance framework. However, there are also specific requirements for individual components of the framework if it is to have diagnostic capacity for informing the selection and design strategic initiatives to enable transitions.

Ferguson et al. (2013) provides a detailed examination of the concept of diagnostic approaches for informing the selection and design of strategic initiatives. In reviewing literature on socio-technical and social-ecological systems in relation to system diagnosis, they propose a scope for a diagnostic procedure that:

- Guides questions about the system that become more specific as new information is discovered
- Is capable of analysis at scales of both the whole system and its individual variables
- Is capable of analysis of both static and dynamic system dimensions
- Is capable of analysis of a system’s external context, actors, structures, processes and outcomes
- Incorporates a methodological framework for consistent application across different cases

- Is underpinned by analytic concepts that can describe and explain system changes
- Is capable of leading to predictions about how strategic initiatives will influence the system dynamics
- Identifies what strategic initiatives best fit the current system conditions for enabling desired changes.

Ferguson et al. (submitted a) conceptually develops a diagnostic procedure that meets the above scope for mapping the dynamics of a current socio-technical system and revealing insight into the types of strategic initiatives that are most likely to steer a transition in a desired direction. The procedure draws on transitions, resilience and institutional literature, and while it requires further development and validation, it sets out clear steps for diagnosing a system's transformative capacity:

1. Define the current system components and envision a desired future system
2. Determine what phase of change each relevant part of system is currently in
3. Determine what system conditions and transition patterns would be likely to result in the system changes required for achieving the future vision
4. Determine what institutional changes would be likely to induce the necessary conditions for enabling a transition
5. Identify the range of mechanisms for acting on institutions in the system to create the required changes for enabling a transition

The proposed meta-governance framework therefore would need to have capacity for guiding an analyst through these five steps in order to reveal how strategic interventions could trigger the required mechanisms for enabling system change.

The framework also needs to be capable of coordinating these interventions in a logical and practical manner for implementation by system actors. To address this question, Ferguson et al. (submitted b) propose a scope, logic and design base of a strategic program for coordinating and aligning action towards achieving a desired long-term future in urban water sectors.

Ferguson et al.'s (submitted b) strategic program was developed by drawing on conceptual insights from strategy and transitions literature, as well as from lessons in the content of a normative transition scenario produced by Melbourne's water practitioners during participatory workshops based on transition arena methodologies (Nevens et al., in press). The strategic program was specifically focused on the transition of a conventional urban water system based on technocratic engineering principles to an adaptive water sensitive system; however, with contextualisation, it would be applicable to other socio-technical systems. The strategic program comprised a series of content and process goals for the following dimensions:

- Set the decision-making context for the long-term:
    - Develop a shared sector-wide *strategic direction* through articulating visions, priorities and objectives that guide all strategic initiatives.
    - Develop a shared understanding of the *system context* by exploring possible future scenarios, challenges and opportunities that would shape the system's performance.
- Establish mechanisms for communication and control in the medium-term:
    - Develop a shared understanding of the *system capacity* by assessing the current and required resources, knowledge and tools across different organisations that could respond to the strategic direction and system context.
    - Develop a series of *strategic options* across organisations to identify and evaluate the most effective options for delivering the long-term vision with the current system capacity
- Establish mechanisms for performance control in the short-term:
    - Develop *programs of action* related to selected strategic options for individual organisations or project teams to allocate resources and responsibilities for implementing actions in specific timeframes.

The various features outlined above provided the scope for guiding the design of an architecture and toolkit of the second generation meta-governance framework for transition management. The scope was synthesised into four key objectives that need to be supported by elements of the framework:

(a) Diagnostic insights about the system's transformative capacity
(b) Selection and design of strategic initiatives that best fit the current system
(c) Learning and innovation through the execution of strategic initiatives
(d) Reflexivity, flexibility and adaptability in the overall system governance

The following section presents the architecture of the framework in relation to these four objectives.

3.2. Framework Architecture

The framework architecture is based on an iterative cycle of six phases (Figure 1). Each phase has specific process and content goals; the process goal is either dependent on the content goal, or vice versa. The cycle demonstrates the sequential content and learning flows between phases, highlighting the type of understanding required during each phase for effective strategic interventions. ‘Content flows’ are actual products that have been developed, such as system data, visions, strategic plans and assessment outputs. ‘Learning flows’ are the insights gained by actors through process participation (in other words, the social learning). There is no prescribed timing for the implementation of each phase and multiple phases are likely to occur simultaneously. For example, there will always be activities occurring for Phase 5 (Strategy Implementation) and Phase 6 (System Monitoring), while Phase 2 (Desired Future System Mapping) may only occur every few years.

In strategic planning literature, Mintzberg (1994) argues that strategic success requires both creative and intuitive thinking as well as the analytic and programmatic thinking that tends to lead to the development of strategic plans (see also Heracleous, 1998). A meta-governance framework for guiding strategic initiatives therefore needs to coordinate these different modes of thinking in a way that will be most effective. Building on Loorbach’s (2010) categorisation of four types of governance activities (strategic, tactical, operational and reflexive), the proposed framework defines six modes of thinking that are required to achieve the process and content goals in the different phases of its cycle. *Strategic* thinking refers to setting direction, synthesising ideas and identifying opportunities within a broad context. *Tactical* thinking refers to calculated and deliberate consideration of how to achieve goals within a specific context. *Operational* thinking refers to determination of how individual actions can be implemented within a specific context. *Reflexive* thinking refers to inward reflection on successes and failures in order to learn from experience and inform future decisions. Two additional modes of thinking are defined for the framework. *Creative* thinking refers to imaginative, divergent and original expression of thoughts and ideas. *Analytic* thinking refers to coherent and logical examination to gain detailed understanding.

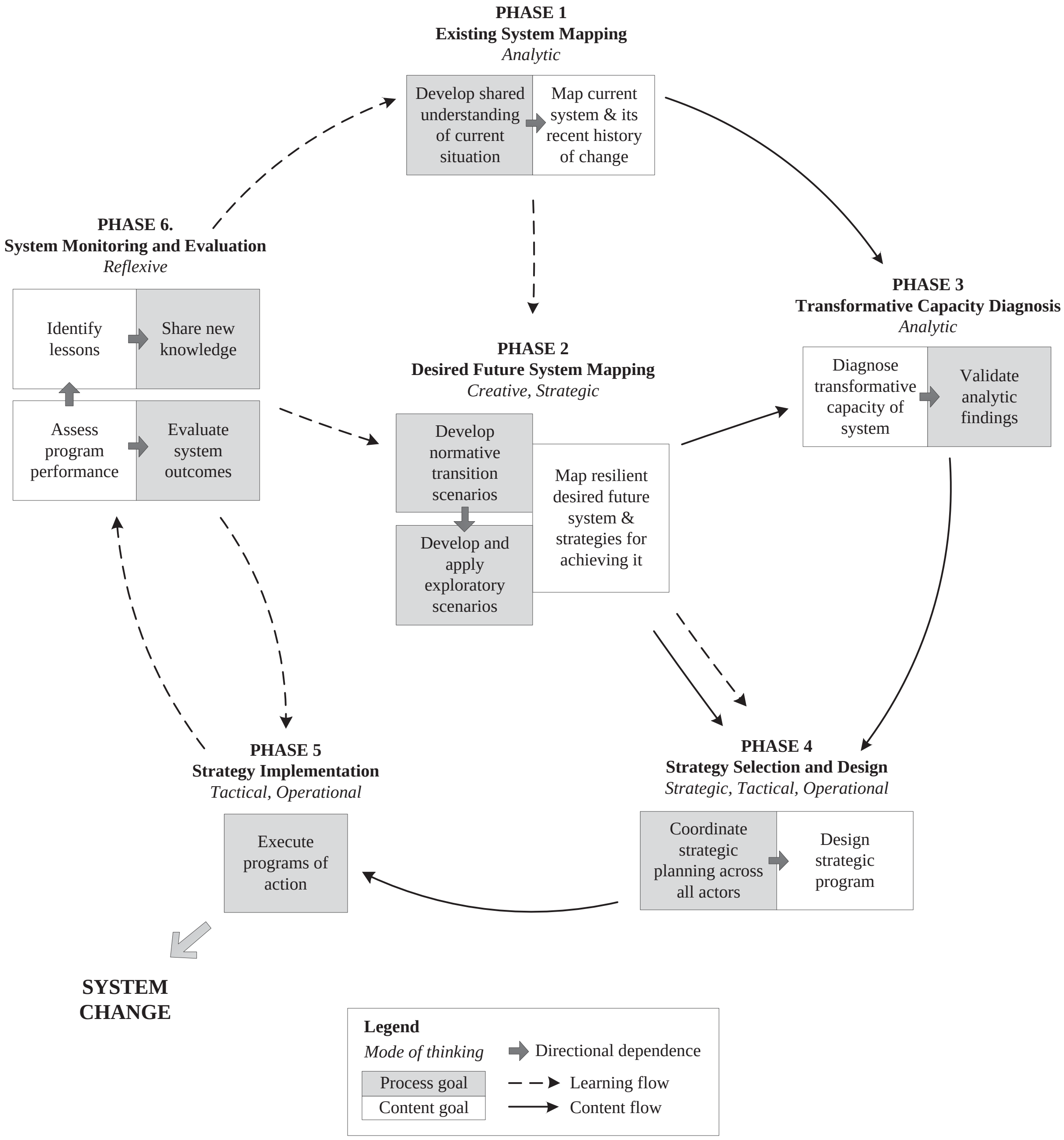

Figure 1. Architecture of proposed second generation meta-governance framework

Phase 1 of the framework aims to map the individual elements of an existing system and diagnose its current phase of change, through processes that allow actors to develop a shared understanding of the system, its recent history and the underlying causes of its persistent problems. These steps require analytic thinking.

Phase 2 aims to map a desired future system in terms of its envisioned composition and pathways for reaching it. This firstly involves processes with system actors to develop a shared vision of the future system (through creative thinking) and brainstorm strategies that could achieve the vision (through strategic thinking). It then involves processes where actors consider how resilience of the vision and pathways could be enhanced to cope with different future contexts and surprises (creative and strategic thinking).

Phase 3 aims to diagnose the transformative capacity of the existing system by contrasting its current conditions with the desired future. Analysis of the outputs from Phases 1 and 2 lead to insights about what parts of the system are receptive to change and the type of strategic initiatives likely to be most effective in steering desired change. System actors need to validate the outputs from this analytic mode of thinking in order for them to be relied upon as a base for developing a strategic program during the next phase.

Phase 4 aims to integrate the outputs from Phases 2 and 3 to design a strategic program for enabling transformative change in the system. This requires coordinated strategic planning processes across the whole system, where all relevant actors are engaged in strategic and tactical thinking. The output of this phase is a strategic program which aligns strategic planning and management initiatives for the whole system, including activities to implement the other phases. For example, the strategic program would need to address the future initiation of processes for Phase 1 (existing system mapping) and Phase 2 (desired future system mapping). In this sense, while design of the strategic program is embedded within the framework, the activities of each phase are delivered by embedding them within the strategic program to allocate responsibility for their actual implementation.

Phase 5 aims to execute the programs of action defined in the strategic program from Phase 4 and as such, there are no content goals. Actual change in the system is achieved in this phase, through the implementation of actions in the specific system context (although the social learning of actors through all phases also contributes to system change). This phase requires tactical and operational modes of thinking.

Phase 6 aims to evaluate the performance of strategies that are executed in Phase 5, through making objective assessments of different elements of the programs of action. This assessment then allows overall evaluation of the system to be conducted with relevant actors, as well as specific lessons to be identified. Processes for sharing these lessons are also part of this phase. Reflexive thinking is at the heart of Phase 6.

The four key objectives for the meta-governance framework synthesised in Section 3.1 are addressed through combinations of phases (Figure 2). Content and process steps for Phases 1, 2 and 3 lead to diagnostic insights about the current system in relation to its capacity for transitioning towards the desired future vision. Steps for Phases 2, 3 and 4 involve the identification of strategic initiatives that are most likely to enable transformative change towards the desired future, given the current system's conditions. Steps for Phases 5 and 6 are focused on implementing action to support learning and innovation in the execution of the strategic initiatives. Steps for Phases 6, 1 and 2 adopt a paradigm of reflexivity, flexibility and adaptability to inform future system directions with the insights from past experiences.

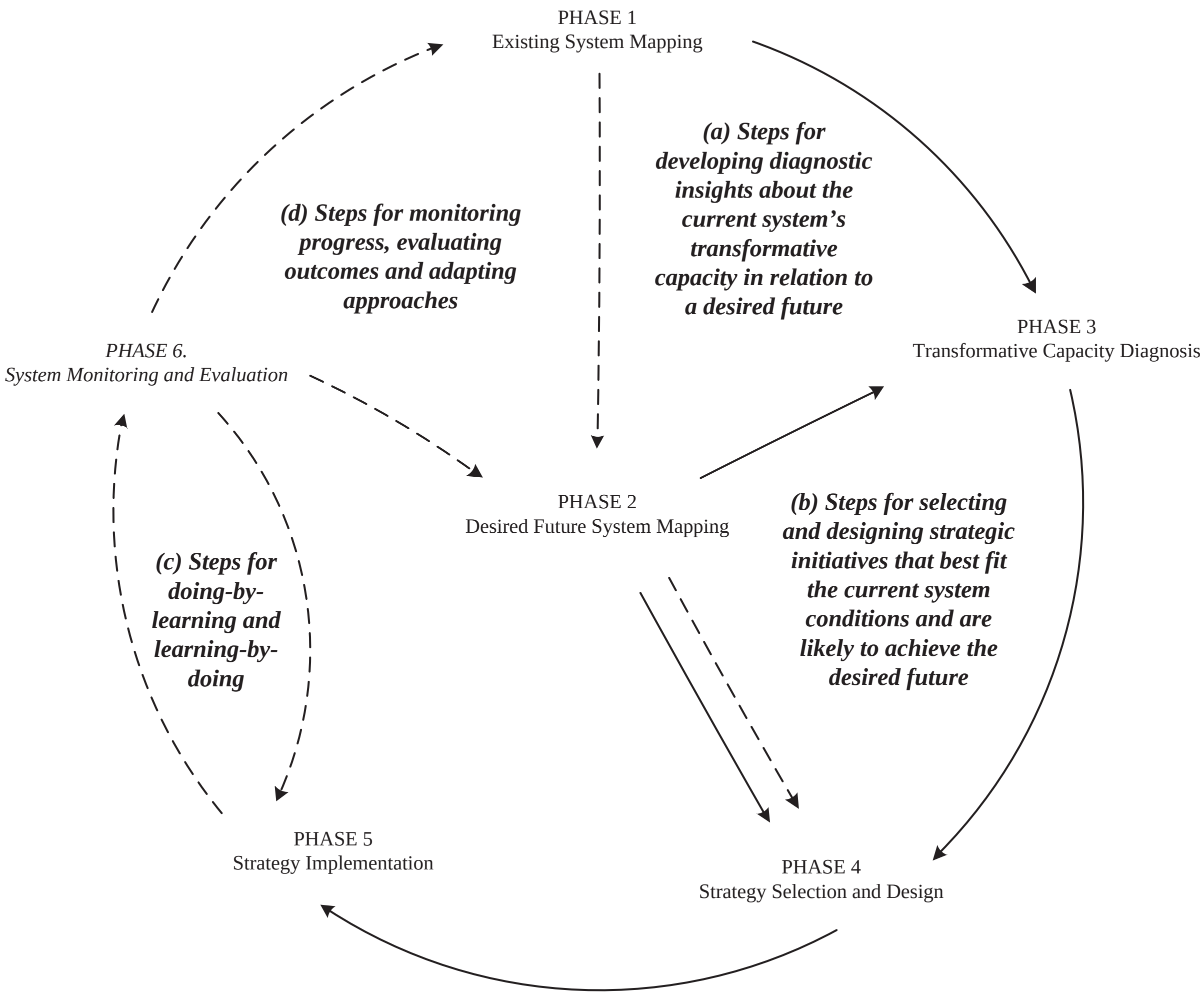

Figure 2. Key objectives for the meta-governance framework: (a) Diagnostic insights about the system's transformative capacity; (b) Selection and design of strategic initiatives that best fit the current system; (c) Learning and innovation through the execution of strategic initiatives; (d) Reflexivity, flexibility and adaptability in the overall system governance.

3.3. Framework Toolkit

Each phase of the proposed framework requires different content and process tools for delivering its goals (the term ‘tool’ is used here in the broadest sense). Content tools support the systematic, logical and detailed examination of a phenomenon (for example, empirical methods, conceptual relationships, theoretical propositions, assessment frameworks, metrics and models). Process tools engage with actors, implement initiatives and facilitate learning (for example, networks, forums, participatory methods, communication devices and policy instruments). Many existing tools from transitions studies fit one or more phases of the framework (Table 1).

The existing tools are at varying stages of development. Some tools are fully operational but require empirical testing and validation. Others are at a conceptual stage and require further methodological development to guide its application. Yet others have theoretical hypotheses embedded within that require empirical testing and validation for the tool to be relied upon. It is beyond the scope of this paper to comment on the current status and necessary future development for the various tools. However, a systematic review of all possible tools associated with transformative change (from transitions literature and beyond) is an important next step in the development of this second generation meta-governance framework. This would also serve to identify critical gaps, highlighting where research should focus to extend existing or develop new tools to support transitions.

The use of particular content and process tools in the proposed meta-governance framework will vary with the stage of a transition. For example, the transition arena process tools are largely designed for shadow track activities which would be most effective in the pre-development stage of a transition. Exploratory scenario tools are likely to be suitable for later stages where the regime needs to consider how it will continue to function in all possible future contexts. As such, the toolkit sits alongside the overall framework architecture and particular tools should be selected to best suit the specific governance needs at different transition stages. Again, further research is required to provide guidance on which tools are most effective at different stages of a transition.

Table 1. Existing transition management tools located in the meta-governance framework.

Phase	Content Tools	Process Tools
1. Existing system mapping	• Multi-level perspective for mapping interactions between landscape, regime and niche scales (Geels, 2002; Geels, 2004; Rip and Kemp, 1998; Smith et al., 2010) • Multi-phase S-curve for mapping different stages of transition processes over time (Rotmans et al., 2001; van der Brugge and Rotmans, 2007) • Multi-pattern approach for mapping patterns of system change over time (de Haan and Rotmans, 2011)	• Transition arena methods for participatory definition of existing system problems (Loorbach, 2010; Nevens et al., 2013; Voβ et al., 2009)
2. Desired future system mapping	• Transition scenarios, including vision and strategies (Sondeijker et al., 2006; Wiek et al., 2006)	• Transition arenas methods for participatory development of long-term future visions (Loorbach, 2010; Nevens et al., 2013; Voβ et al., 2009) • Transition arena methods for participatory backcasting of strategic transition pathways (Phdungsilp, 2011; Quist et al., 2011; Robinson et al., 2011) • Methods for participatory development of explorative context scenarios and wildcards (Saritas and Smith, 2011; van Notten et al., 2005; Walker and Salt, 2006; Wardekker et al., 2010)
3. Transformative capacity diagnosis	• Theory on the dynamics of transitions, validated with empirical research (Geels and Schot, 2007; Ferguson et al., submitted c) • Operational diagnostic procedure for transformative change (Ferguson et al., 2013; Ferguson et al., submitted a)	
4. Strategy selection and design	• Strategic program for transformative change (Ferguson et al., submitted b). • Design framework for creating social learning situations (Bos et al., 2013). • Framework for understanding power and legitimisation in transition processes (Grin, 2012)	• Methods used in transition arenas for participatory development of transition agendas (Loorbach, 2010; Nevens et al., 2013; Voβ et al., 2009) • Transition arena processes for fostering shadow actor networks (Loorbach, 2010; Olsson et al., 2006; Voβ et al., 2009)
5. Strategy implementation	• Competence kit (learning module) for practitioners involved in transition experiments (Raven et al., 2010) • Framework of success factors in governance experimentation (Bos and Brown, 2012)	• Transition experiments for stimulating innovation (Farrelly and Brown, 2011; van den Bosch, 2010) • Strategic niche management processes for incubating and up-scaling innovation (Raven and Gregersen, 2007; Schot and Geels, 2008)
6. System monitoring and evaluation	• Organisational capacity assessment framework (Bos and Brown, submitted)	• Processes for knowledge generation and sharing (Berkes, 2009)

Note: This list is not exhaustive but serves to highlight common tools referred to in transitions literature. Only selected references are indicated.

4. Using the Framework

While there will be no one privileged position for an actor to steer a system's trajectory, the meta-governance framework provides a logic and architecture for coordinating the activities of multiple actors who seek to intervene in a system to enable a transition. These actors could be scientists, strategic planners, policy analysts and decision-makers with formal roles and responsibilities in a system, or they could be operating outside the existing regime as part of an informal network. In fact, the actors who are involved in governance initiatives of a system will largely depend on the stage of a transition. For example, during the pre-development stage it is likely that the governance activities identified in the framework will be conducted informally as part of a shadow network, while the stabilisation stage may require the fundamental involvement of mainstream governance actors in strategic planning and implementation activities.

The decision of when and how the regime should be involved needs careful consideration. While individual regime actors may be innovative and make a valuable contribution to shadow track activities, the regime as a whole will potentially stifle creativity, experimentation and innovation if it is engaged too early in a transition, since resistance to change is a core part of a regime's characteristics. On the other hand, regime involvement will eventually be critical for a transition to be achieved, particularly in systems where the aim is not regime replacement but adaptation (urban water servicing is a prime example of such a system). From research undertaken in the development of this paper, it would anecdotally seem that the most effective time to engage with the regime is when the transition is sufficiently progressed to already have substantial momentum, evidence and commitment, so that the existing regime can be convinced of the value in adapting its approach. However, further research is required to develop guidance about when and how a regime is best brought into transition governance processes.

The proposed second generation transition management framework is generic and can be utilised at different operational scales and contexts. For example, while it is well suited to an urban water sector that comprises integrated scales of infrastructure and a diversity of actors, it could equally be applied to a particular technological industry, a social-ecological system or an individual organisation that needs to undergo transformative change. This flexibility comes with its meta-governance nature, since the aim of the framework is not to replace existing governance processes. Instead it is designed to complement them, linking diagnostic insights about a system's transformative capacity with governance processes to enhance the effectiveness of strategic initiatives for enabling a transition.

5. Conclusions

This paper proposed a second-generation meta-governance framework, building on the established foundations of transition management. The logic of the framework architecture and toolkit sets the direction for transitions researchers to coordinate the focus and outcomes of future activities. With this coordination, the next wave of transition management scholarship can work towards developing the capacity to critically inform the selection and design of strategic initiatives with diagnostic insights into how change can most effectively be influenced during all stages of a transition.

The paper has highlighted a number of areas where significant research is required to develop this capacity within transition studies. First, existing tools within literature on transitions and transformative change should be systematically reviewed to take stock of established capacities and reveal critical knowledge gaps that require attention. Examination of which process and content tools are most effective for different stages of a transition should also be undertaken so that transition management concepts can be extended beyond the pre-development stage. Insight into the type of actors (from niches and regimes) and their roles, relationships and responsibilities during different stages of a transition is needed so that guidance for governance processes can be developed. Substantial empirical evidence about the patterns and trajectories of transformative change is needed so that reliable theory on transition dynamics can be developed to support diagnostic assessments of a system's transformative capacity. Finally, the influence of actor strategies on these transition dynamics needs empirical examination and theorising so that best-fitting strategic initiatives can be selected and designed.

There is clearly a full research agenda for the development of the next generation of transition management concepts. While debate about the potential, politics and practicality of deliberately steering transformative change is important and set to continue, the question of how actors can influence system change effectively is critical if society is to address growing challenges around the sustainability and resilience of socio-technical systems. As such, we look forward to new and valuable insights to inform these issues from transitions research in the coming years.

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Transitions in the energy system: The strategies of new firms commercializing advanced renewable energy technologies

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Abstract

The paper discusses the entry strategies adopted by research-based firms introducing advanced renewable energy technologies in the electricity production sector. Because these firms operate in an environment that combines fast technological change and strong incumbent power, this provides a good setting to address the interactions between niche innovators and regime incumbents. Drawing on contributions from the literatures on sustainability transitions and on strategic management of technology we build an analytical framework to address the conditions faced by the new entrants, the strategies they adopt, the nature the relationships they establish with incumbents and the attitudes of the latter towards their technologies. This framework is applied through in-depth case studies of new firms in two energy niches that display different levels of technological maturity: wind and wave energy. The paper presents preliminary results from a first set of case studies, which provide some insights into the "commercialisation environment" prevailing in those fields. They suggest that research-based firms tend to depend on the complementary assets possessed by incumbents, but have conditions to protect their technologies; and that the technology is relevant for (at least some) incumbents, which show interest on them, or are directly involved in their development/use. This is, in most cases, conducive to "cooperation" strategies, which assume different forms, according to the stage of development of the technology and its proximity to incumbent competences and business models. The results, although still preliminary, contribute to a better understanding of how these firms act to introduce their technologies, how they relate with regime actors and how the conditions found in the particular environment where they operate influence their potentially disruptive behaviour. Thus, they adds to our knowledge about the role of entrepreneurial firms in energy transitions and provide some insights into nature of the (business-level) niche-regime interactions that take place along these processes.

Keywords: energy transitions; actor behaviour; niche-regime interaction; commercialization strategies

Transitions in the energy system: The strategies of new firms commercializing advanced renewable energy technologies

1. Introduction

This paper investigates the strategies adopted by new research-based firms to commercialise renewable energy technologies that can contribute to a sustainable transformation of the electricity production sector.

Given its scale, complexity and contribution to the functioning of modern societies, the energy system can be described as a major socio-technical system (Verbong and Geels, 2010). Transformations in the way key societal functions are fulfilled – or socio-technical transitions - are complex processes that can place along decades and involve far reaching changes not only at technological but also at institutional, organizational and social levels. These processes have been addressed by the various streams of the sustainability transitions literature (Markard et al, 2012). One of these streams – the multi-level perspective (Geels, 2002) – conceptualises transitions as the product of interrelated processes at three levels: niche, regime and landscape. Radical innovations that may come to play a role in regime transformation are developed in niches that act as protective spaces, temporarily shielding them from the selection pressures exerted by the dominant regime. Changes at the landscape level may introduce some destabilisation in the regime and create opportunities for niche innovations, which, may break through and profoundly transform or even overthrow the dominant regime.

However, previous research has shown that the way these processes unfold varies, revealing differences in the role played by niche and regime actors, in the type and extent of the interactions between them, as well as in the final outcome (Geels, 2002; Foxon et al, 2010; Kemp and Van Lente, 2011). A number of transition routes or patterns have been suggested by the literature (Geels and Shot, 2007; Smith et al, 2005) and research has increasingly focused on the actual process of niche breakthrough and on the implications, for niche development, of its interaction with the regime within which it emerges (Shot and Geels, 2007; Smith and Raven, 2012). This also called for a more detailed investigation of the micro-level behaviour of actors involved in these processes (Markard and Truffer, 2008; Farla et al, 2012), both niche innovators striving to develop, legitimise and diffuse their technologies (Avdeitchikova and Coenen, 2013; Kishna et al, 2011; Wustenhagen and Wuebker, 2010) and powerful regime actors confronted with disruptive innovations (Smink et al, 2011; Thurnheim and Geels, 2012).

The objective of this paper is exactly to contribute to this micro-level research, by addressing the strategies of entrepreneurs introducing potentially disruptive renewable energy technologies in the electricity production sector and, in particular, their relationship with powerful regime actors – the large energy production and distribution companies and the large energy equipment manufacturers that dominate the sector.

A process of transition to sustainability is already underway in the energy system. While it is not yet clear how the process will unfold, a trajectory whereby niche innovations break through, overthrow and replace the established regime is unlikely, given the infrastructural nature of the energy system. Rather a process that involves some forms of interaction and integration between regime and niche actors and their technologies and practices, potentially resulting in some basic reconfigurations in the regime architecture, appears as more probable (Verbong and Geels, 2010).

Thus, even if transitions are complex undertakings involving a wide variety of processes and actors, it still appears to be relevant to look in some detail into specific aspects of the interactions taking place, at the micro-level, between individual actors. The analysis of the strategic behaviour of a particular group of niche actors – new research-based firms exploiting emerging energy technologies - may provide us with some insights into the strategies open to radical innovators and the nature of incumbents involvement in the development and diffusion of these innovations .

For this purpose we combine contributions from the sustainability transitions literature – in particular the MLP and other recent research on niche breakthrough – with contributions from the strategic management of technology literature. The former contributes to a deeper understanding of the ongoing transformations in the energy system: the tensions in the dominant energy regime; the opportunities they generate for new entrants endowed with new technologies and attitudes and the incumbents' attitude towards them (Jacobsson and Bergek, 2004, Verbong et al, 2008; Foxon et al, 2010; Sine and David, 2003). It also provides insights into the generic mechanisms at work as part of the process of niche development and niche breakthrough (Kemp et al, 1998; Hendry et al, 2007; Raven, 2007; Schot and Geels, 2007; Smith, 2008; Smith and Raven, 2012). But, while the disruptive role of entrepreneurs and their capacity to gaining other actors – namely regime actors - to support the development and diffusion of their innovations is widely recognised (Raven, 2007), this literature still pays limited attention to their strategic behaviour (Alkemade et al, 2011). In particular, to how entrepreneurial firms effectively act/interact with powerful regime actors to introduce their potentially disruptive technologies. The strategic management of technology literature contributes to fill this gap, by providing conceptual instruments to address the conditions for exploitation of new technologies by new entrants, in industries dominated by large incumbents (Teece, 1986; Arora et al, 2001, Colombo et al, 2006) and, more specifically, to assess their strategic positioning (Gans and Stern, 2003).

Combining these contributions we develop a framework to investigate the strategies of new firms exploiting niche technologies and their interaction with regime incumbents. In this paper we present preliminary results, based on a small set of cases, where this framework is applied to the analysis of Portuguese research-based firms active in two renewable energy niches – wind and wave – in different stages of development.

2. The changing environment in the electricity sector

2.1 Conceptualising transitions in the energy system

New firms developing renewable energy technologies that have an application in the process of electricity generation and/or distribution are entering a sector that is both highly complex and undergoing profound changes.

The sector is responsible for the production and supply of a basic resource – electricity – whose availability is critical for the functioning of the economy and the society at large. It is one of the largest sectors in the economy, encompassing a wide range of activities associated with the production, transmission and distribution of electricity, which tend to be highly centralised, given the infrastructural nature of the system. Until recently the sector relied on relatively mature technologies and incremental innovation. It was controlled by large national utility operators (frequently under public monopoly) and by large equipment manufacturers (often multinational companies), being characterised by strong economies of scale (Jacobsson and Bergek, 2004).

But more recently the sector has been experiencing profound changes, driven by the liberalisation of energy markets and by pressures for reducing dependency on fossil fuels (Jager-Waldau et al, 2011; Verbong et al, 2008). The evolution of the sector and the impact of these changes on the sectoral regime have been addressed by authors drawing on a sustainability transitions conceptual framework (Verbong and Geels, 2010; Foxon et al, 2010; Jacobsson and Bergek, 2004; Hekkert and Negro, 2009). Among the various streams of the transitions literature, the multi-level perspective (Geels, 2002; Geels and Schott, 2007), provides a useful analytical framework to understand the structural rigidities that characterise this large infrastructural system, as well as the conditions in which a process of transition to a more sustainable system may unfold (Verbong and Geels, 2010).

According to this framework changes in large socio-technical systems - as the energy system - are difficult to achieve because they involve major transformations on the ways the system fulfils its functions, which are embodied in the dominant socio-technical regime, characterised by strong path dependence. The regime accounts for the stability of the system, guiding and constraining the behaviour of its actors and guaranteeing its own reproduction[1]. However, pressures originating at the landscape level may create tensions and lead to regime destabilisation, providing opportunities for the emergence of innovations with a transformative potential that are being developed in niches - such as those associated with renewable approaches in the energy case. Niches are protected spaces that shield innovations from the regime selection environment, but where processes of nurturing and empowerment may also take place, which can ultimately lead to innovations breaking out of the niche and bring about regime shifts (Kemp et al, 1998; Smith and Raven, 2012). However, these processes are far from being straightforward, requiring profound changes not only at the technological but also at the social, institutional and political level, which are resisted by regime actors and institutions. Besides, they may unfold along different paths, involving a variety of developments both internal to the niche, between competing niches and in the interplay between niche and regime (Geels, 2005; Raven, 2007) and may lead to different outcomes.

It is therefore relevant, from the standpoint of our research, to try to work out what changes are taking place, as part of the development of the renewable energy niches, in order to understand which is the space for new firms introducing emerging renewable energy technologies and whether and how these niche-level actors are interacting with regime actors.

2.2 The emerging renewable energy sector

Drawing on the above approach, it is possible to argue that the changes underway have already introduced some destabilisation in the prevailing electricity production regime, leading to alterations in the sectoral knowledge base and in the industrial structure. The liberalisation of the energy sector, that took place in the majority of European countries, brought about the extinction of public monopolies, with transmission of ownership and management to private companies operating in a competitive market (Jorgensen, 2005). It also forced the separation between energy production, transmission, distribution and commercialisation, which required established companies to reorganise their activities and reconfigure their strategies (Markard and Truffer, 2006) and made market entry comparatively easier, at least in some segments (Verbong et al, 2008).

The need to achieve a lower dependence on fossil-fuel and pressures towards cleaner production led to the introduction of policies promoting the introduction of renewable energy sources (Jager-Waldau et al, 2011). This opened new opportunities for potentially disruptive renewable technologies that were

[1] In the case of the electricity system, the socio-technical regime is characterised by the interplay between "material and technical elements" including generation plants, production resources, grid infrastructure; "networks of actors and social groups" including utilities, large industrial users, domestic consumers and government bodies with responsibility in the sector; "formal, normative and cognitive rules that guide the activities of actors (e.g. regulations, belief systems, guiding principles, search heuristics, behavioural norms)" (Verbong and Geels, 2010: 1215)

being developed in niches, given the still high technological and market uncertainty associated with their exploitation. Competing technologies based on different energy sources and on different modes of exploiting these sources were in different stages of maturity and underwent diverse development processes (Verbong et al, 2008). Some of them have now reached a stage where wider commercial exploitation became viable, especially in countries that introduced market-oriented policies. This is particularly the case of wind energy that is the most widely diffused renewable source, despite the problems associated with its intermittent nature (Kaldellis and Zafirakis, 2011).

The creation of a growing space for renewable energies drove a renewal of the industry knowledge base. There was a fast increase in the level of R&D, patenting and innovative activity, largely fuelled by government policies that sponsored research or provided incentives for the development or implementation of renewable technologies (Ayari, 2012; Johnstone et al., 2010). The emergence of technologies that substantially departed from the incumbents' knowledge base created opportunities for the new firms that developed or exploited them. The distributed nature of some of the new energy sources also favoured new entry, which was further encouraged by a variety of incentives for their production and use (Schoettl and Lehmann-Ortega, 2010).

These transformations challenged the dominant position of energy utilities (Duncan, 2010) and led to some readjustments in the actor composition and balance of power (Verbong and Geels, 2010). However, although the introduction of renewable technology may have created some internal tensions in the regime and caused some reconfigurations in its architecture it did not radically change the system basic structure or dislodged its dominant players.

First of all, in most countries renewable sources still provide only a minority of the electricity produced and the system is still largely fed by conventional sources that, together with large scale hydropower plants, still shape the electricity dominant regime (IEA, 2011). This is a centralised regime that matches the competence and assets of large regime players (Duncan, 2010). Furthermore, with some exceptions (e.g. wind is some locations), energy production from new renewable sources still did not reach cost parity with that originating from fossil fuel sources and also raises several system level problems (e.g. grid integration) (Jacobsson and Bergek, 2004; IPCC, 2011). Thus, the renewable business is strongly dependent on government policies, which may change, associated with political and economic cycles (Verbong et al, 2008). Consequently, its expansion is affected by the capacity of its promoters - companies or trade associations, research organisations, social movements - to influence the decisions of governments and other critical actors (Jacobsson and Lauber, 2006). It is also vulnerable to "capture" by powerful regime actors (Kern and Smith, 2008; Smink et al, 2011).

On the other hand, regime actors have become increasingly engaged with niche-level innovations, being able to absorb and integrate at least some of them (Bergek et al, 2013). In fact, along the process of development and diffusion of renewable energies, it was possible to observe a growing involvement of some regime actors with the more mature technologies - in particular those that were closer to their competence base, both in technological and in organisational terms. This involvement is likely to have influenced the development trajectory of some technologies and their mode of deployment (Geels and Schot, 2007), namely favouring large scale centralised systems that better match their competitive advantages. The case of wind energy is a good illustration of these effects. The configuration of the emerging sector, made it attractive to incumbent, both energy utilities or equipment manufacturers that were able to reconfigure their business, redeploying their assets and competences to enter the new field; and large firms that diversified from other sectors, attracted by favourable policies and often profiting from competences in complementary fields (e.g. metalomechanics or construction).

Thus, in more mature renewable segments where markets started to develop, regime actors ended-up joining and competing with the *de novo* entrants - firms that had pioneered the development of specific technologies and had been able to grow on the basis of innovation and first mover advantages (Dewald and Truffer, 2011).

2.3 Implications for new firms introducing advanced technologies

Which are the implications of these processes for new technology-intensive firms introducing advanced renewable technologies?

It can be argued that a renewable electricity production sub-sector has already emerged in those segments and countries where renewable technologies have reached maturity and achieved some market diffusion. This sub-sector is currently characterised by fast technological change and by an industrial structure where large established firms tend to occupy dominant positions. Moreover, it is closely interlinked – in terms of activity and actor composition - with the more global electricity production, transmission and distribution sector. Thus it can be expected that behaviour of the renewable energy actors will be influenced by the sector's operational and institutional logics.

However, the renewable energy field is diverse and heterogeneous and, as a whole, it is far from being stabilised. In fact, the promotion of energy production from renewable sources created incentives for the emergence of a variety of competing energy conversion approaches and technologies, giving rise to a diversity of trajectories. Currently we find technologies in different stages of development, market introduction and adoption, ranging from those that reached commercial stage and achieved some market diffusion (such as large scale wind conversion or first generation solar photovoltaics) to those where a dominant design is still to emerge (such as wave conversion) (Jäger-Waldau et al, 2011; IPCC, 2011). This has implications in terms of the conditions faced by technology-intensive firms operating in the respective niches, influencing the opportunities that are created and the way these can be exploited. It also influences the attitude of the firms established in the sector and of other key actors (capital providers, policy makers, consumer groups) towards new entrants and their technologies.

Regarding the opportunities open to the new firms, the positioning of powerful companies in more stabilised renewable segments, raised entry barriers and drove out entrepreneurs from the core activities. But even in these fields, there is still a variety of complex problems that require extensive technological developments (incremental innovations). These include problems associated with the operation of the actual technologies (efficiency, costs, reliability) and new system-level problems that emerged due to their distributed and intermittent nature. This creates opportunities for technology-intensive suppliers that offer established actors advanced solutions for these critical problems.

On the other hand, the still relatively unsatisfactory performance of renewable sources in terms of energy yield, costs and security of supply opens some space for the emergence of alternative designs (e.g. new modes of wind conversion or third generation photovoltaic cells) which are often being developed and tested by new firms. The same happens in the case of technologies that favour a distributed production system, as opposed to centralised or grid-connected systems. New entrepreneurial firms are also important actors in the case of emerging renewable sources that have not yet reached a commercial stage. In all these areas we observe a variety of competitive technologies being developed by different firms, often still at research or experimental stage (IPCC, 2011). The positioning of new firms in this type of activities is not unexpected. In fact, the opportunities created by technologies that depart substantially from the established knowledge base tend to be identified and exploited by new firms that originate from outside the industry (Winter, 1984). This is, namely the case of research-based spin-offs that base their competitiveness on the quick paced exploitation of knowledge originating from scientific research (Mustar et al, 2006).

Incumbent companies vary in their attitude towards less mature, fast evolving or still emerging technologies (Ansari and Krop, 2012; Bergek et al, 2013). Established companies are often reluctant to getting involved in the early exploitation of more immature technologies, given the high uncertainty and their lack of competences (Levinthal, 1997). Thus, as pointed out above, energy companies repositioning themselves in the renewable field, or companies diversifying from other sectors are more likely to invest in stabilised fields and technologies and in innovation promote projects that are closer competences and competitive advantages (Hockerts and Wüstenhagen, 2010; Duncan, 2010).

But the growing international competition in the energy area has quickened the technological pace and increased the pressure to invest in innovation, and thus the need to look for new technologies, or get involved in alternative technological paths (Hekkert and Negro, 2009). Thus incumbents may wish to keep an eye on the new developments, in order to follow-up (or even influence) their evolution and/or to guarantee an early position, once a dominant design starts to emerge (Sine and David, 2003). But they usually prefer to achieve this through collaborations that reduce the risks and costs involved (Dyerson and Pilkington, 2005). This may assume different forms, from simple technological watch, to participation in research activities (often coordinated by research organisations), to greater involvement with the firms that are developing the new technologies. The latter can include funding of entrepreneurial activities, participation in demonstration projects to test/validate the technology, alliances with firms whose technologies are perceived to have future potential, or answer to existing needs (Hockerts and Wüstenhagen, 2010; Dyerson and Pilkington, 2005; Teppo and Wüstenhagen, 2009). The presence and interest of large incumbents can be important for the development of the niches where these new technologies are exploited, since they convey resources and legitimacy and can make them attractive to other key actors, such as capital providers (Schot and Geels, 2007).

Thus, we are faced with a context that combines strong incumbent power and fast technological change and where at least some regime incumbents recognise the need to explore new trajectories and thus reveal interest in the niche technologies being developed by entrepreneurial firms. This combination creates a particular competitive environment that has implications for the interaction between the new firms exploiting niche technologies and the regime incumbents.

3. New firm strategies in conditions of incumbent dominant position

3.1 Conditions for entry of technology-intensive start-ups

The conditions faced by new entrants in an environment that combines fast technological change and strong incumbent power and the strategic opportunities open to them have been addressed by the literature on the strategic management of technology (Teece, 1986; Arora et al, 2001). According to this literature, the capacity to protect the technology and the conditions of access to a number of downstream resources or competences that are necessary to sell a complete product/service – the "complementary assets" - are basic elements in the start-up strategic decisions. In particular, it has been shown that when large incumbents control a number of key complementary assets, small technology-intensive entrants may benefit from adopting "cooperation strategies" (Gans and Stern, 2003), entering in relationships with them (Colombo et al, 2006).

Technology-intensive start-ups are typically small firms with strong knowledge competences, but limited financial resources and frequently missing market-related competences and networks (Arora et al, 2001; Mustar et al, 2006). Thus, when attempting to commercialise their technologies they have to make some strategic decisions regarding critical complementary assets. They can build (some of) them internally, can try to gain access to them, through market transactions or through alliances, or else, can focus on technology development and licensing, avoiding any involvement in downstream activities (Arora et al., 2001). The decisions made at this level are strongly influenced by the nature of the assets, in particular those that are key to capture rents from the innovation.

In fact, complementary assets can be generic and supplied by the market in competitive conditions, or co-specialised to the innovation (Teece, 1986). Co-specialised assets may not be readily available in the market, since their owners try to achieve control over them, and they may also be difficult to imitate, because they are built on the basis of a process of learning within the firm (Rothaermel and Hill, 2005). In these cases, access to these assets may require the establishment of a contractual relationship with the owner (Aggarwal and Hsu, 2009; Colombo et al, 2006; Shan et al, 1994). The problem is compound when such assets are owned by established, often powerful firms, which may not be easily gained to such relationships, or may use their position to appropriate a substantial part of the rents from the innovation (Rothaermel and Hill, 2005).

In the limit the new firm may choose to avoid engaging in the development of products/services and commercialise the technology instead (Conceição et al, 2011). However the literature describes a variety of vertical alliances where the owners of the needed assets - to whom the new firms technologies/products are particularly interesting (Rothaermel, 2002) - assume part or all the manufacturing and/or commercialisation activities (Colombo et al, 2006; Stuart et al, 2007). Indeed, in some sectors incumbents deliberately encourage the development of new and complementary technologies by research-intensive firms (Gawer and Cusumano, 2008; Orsenigo et al, 2001). These alliances also have benefits for the start-up, enabling it to access markets and supply chains; providing capital for technology development and sometimes conditions for the testing of its technologies/products and offering legitimacy (Baum et al, 2000).

But, although these alliances can be mutually favourable, they tend to be characterised by power asymmetry between partners (Shan et al, 1994; Rothaermel, 2001). This asymmetry increases the appropriability hazards, making new entrants vulnerable to the expropriation of their main (or even unique) asset (Teece, 1986). This may deter firms from establishing some types of alliances, unless they can resort to strong intellectual property protection (Katila et al, 2008). In the case of small firms, formal appropriation mechanisms, like patents, are often the only effective means of protection, being particularly important for technology suppliers (Arora and Merges, 2004). In summary, although firms run effective risks when partnering with powerful incumbents, they may need to consider that strategic option (and eventually obtain a return from it) depending on the characteristics of their innovation, the variety of potential partners and their incentive/opportunity to behave opportunistically, the value of the resources provided by the partner and the protection mechanisms available (Katila et al, 2008; Dyer and Singh, 2008).

3.2 The impact of the "commercialisation environment" on firms' strategic decisions

The strategies open to new technology-based entrants were addressed in detail by Gans and Stern (2003), who argue that the characteristics of the "commercialisation environment" constrain the choices to be made by the entrepreneurs. They define commercialisation environment along two dimensions - the extent to which innovation by the start-up precludes the incumbent's development and the relevance of incumbent complementary assets to the start-up – and devise a typology of environments and associated strategies. This framework is relevant for our purposes, since it addresses the type of conditions that may influence the attitude of incumbents towards the advanced technologies being developed by new energy firms and the nature of the relationships that may be established between both.

The environment labelled by the authors as "ideas factories" configures a set of conditions that is likely to emerge in the renewable energy sector. In this case, invention by the start-up precludes effective development by established firms, because the start-up ability to protect the technology makes its appropriation difficult; but established firms control the complementary assets required for its commercialisation. This environment is conducive to a "cooperation strategy", which may range from the licensing of the intellectual property, to the establishment of a variety of strategic alliances to, in the limit, the acquisition of the start-up. For incumbents, relationships with several innovative start-ups offer a fertile source of new ideas in fields where they have limited competences and/or where uncertainty is still too high and thus experimentation with a variety of competitive paths is still required (Raven, 2007). But, while they effectively reduce the start-up's investment in downstream assets (Arora et al, 2001) and offer advantages in terms of legitimacy building, very often they strengthen the basis for incumbents' advantage and thus their market power (Gans and Stern, 2003).

However, Gans and Stern (2003) also argue that when incumbent complementary assets are less important and the technology can be protected from appropriation - the "greenfield competition" environment - the start-up may consider the choice between collaborating and competing. The ability to control the development of platforms and standards is critical if the start-up decides to engage in product market competition. Cooperation is equally an alternative and in this case the start-up has stronger bargaining power and can define where and which conditions to cooperate.

3.3 A framework to analyse the strategic behaviour of new energy firms

In order to investigate the nature of the interactions between entrepreneurial firms and regime incumbents along the process of exploitation of the new renewable energy technologies, we developed a conceptual framework to address firms' positioning that builds on and extends Gans and Stern (2003) concept of commercialisation environment. This framework considers the interplay of three main analytical dimensions:

1) The relevance of incumbents' complementary assets for the new firm to capture the value of its technology.

   At this level we assess the start-up need for and mode of access to those assets. We distinguish, first of all, between firms that avoid engaging in the development of products/services based on the technology and thus *skip the need for those assets*; and those that at least partly engage in the activities necessary for such development and thus *require downstream assets* (Arora et al, 2001).

   In the case of those who need to gain access to some assets, we consider the established distinction between assets mostly *supplied competitively in the market* and assets co-specialised to the innovation and mostly *controlled by incumbents* (Teece, 1986).

   The need for assets is conducive to cooperation strategies, although the conditions in which assets can be accessed has implications for on the type of relation established.

2) The positioning of incumbents relatively to the technology exploited by the new firm.

   At this level we assess whether the technology is relevant for the incumbent. Three generic levels of incumbent potential involvement are considered: keep a *watch* on the activities conducted by the developers of the technology; show *interest in their development*, expressed through direct participation (investment), or through the use of the resulting IP, products or services[2]; be involved in the development and/or commercialisation of *competitor* technologies.

   The two first levels are conducive to a cooperation strategy with new entrants, while in the third there may be competition between them.

3) Whether the new firm can preclude appropriation.

   The extent to which the *need to* rely on complementary assets (in particular co-specialised assets) controlled by the incumbents and/or the *involvement of the incumbents* with the technology may bring about the threat of appropriatio*n* depends (at least partly) on the firm's c*apacity to protect the technology*. Thus we also consider the *protection mechanisms* available to the firm.

[2] Besides the mode of involvement it is also relevant to take into account the incentive and, especially, the capacity of the incumbent to use the relationship to appropriate the technology (Diestre and Rajagoplan, 2012). This capacity may be higher when there is greater technological proximity between partners (Cohen and Levinthal, 1990; Dushnitsky and Lenox, 2005), which could provide potentially more valuable alliances (but which may also entail greater risk).

This framework supports an exploratory analysis of the relational behaviour of research-based start-ups, in the process of early development and commercialisation of their technologies, with a view to answer to the following questions:

- Which is the competitive environment faced by research-based firms introducing renewable energies in the electricity production sector; and which is their strategic positioning relatively to the large incumbents and the type of relationships established with them?
- To what extent these strategies/relationships differ according to the stage of development of the technologies they exploit and niches where they operate?

4. Empirical research: setting and methodology

In order to answering to these questions, exploratory research is underway on the process of technology development and commercialisation conducted by a set Portuguese research-based spin-offs in two renewable energy fields – wind and wave energy. In both fields there is evidence of involvement by energy incumbents, but there are great differences between the wind and the wave technologies and the respective "niches" concerning the degree of maturity of the technologies, the level of market development and the structure of the supportive networks. Thus, it is expected that these differences generate variation in the competitive environment and therefore, on the behaviour of new entrants and incumbents. The empirical analysis is based on a detailed analysis of the process of creation and early development of the firms, grounded on two types of data: in-depth interviews with the founders; documentary information on the firms and on the research, business and institutional setting where they operate.

In a first stage we selected, four companies for preliminary case studies, which were the object of the analysis presented in this paper. In this first selection there was an attempt to include some variety in terms of maturity of the technology, firm age and also type of business adopted by the firms. The firms operate in the following areas, whose technological maturity can be roughly located in a scale of maturity as shown in Figure 2:

- ***Wind***: Plant optimisation; High-altitude wind; Off-shore engineering services
- ***Wave***: Engineering solutions (products & services); Conversion systems

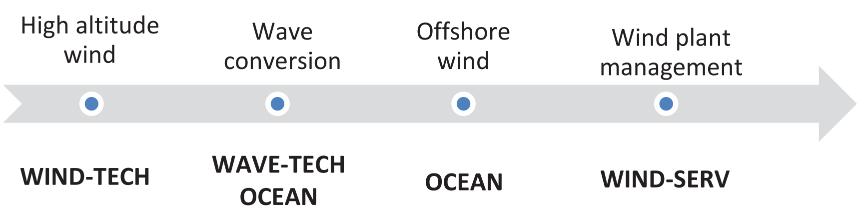

Figure 1 – Firms in case studies

In order to situate these firms in the environment where they operate, we will provide a brief overview of the Portuguese situation in what concerns the diffusion of renewable energies for electricity production, the creation of new firms exploiting advanced renewable technologies and the generic characteristics of the two niches addressed.

4.1 A brief overview of the renewable energy sector in Portugal

Portugal was regarded as providing a good empirical setting for this research given its position as one of the European countries with greater penetration of renewable energy in electricity production and also with more ambitious targets regarding its future development (MEID, 2010). In fact, in the last decade the country invested strongly in the development of renewable energies, both at the research and at the industrial level. It also introduced a very favourable incentive regime for the production and use of energy from renewable sources[3]. Policy documents presented the development of competences and industrial activities in renewable energies as a driver of the country's progress and offered a "vision" of Portugal as an exemplary case of their use, which was largely diffused by the media, creating certain hype around the field.

As a result of these efforts, the contribution of renewable energy sources to the country's gross electricity consumption reached about 50% in 2010. This amounted to an installed capacity of around 10000MW, of which about 50% correspond to hydropower (where there is a longstanding tradition) and another 40% to wind. Other sources have a smaller contribution: biomass (including co-firing) amount to 5% and solar photovoltaics to only 1%. In 2009 Portugal ranked third among the EU15 countries regarding the proportion of renewable sources in electricity production and was fourth in the ranking of countries with the highest penetration of wind power. However, the continuity of these efforts may be threatened by the economic and financial crisis. In fact the energy policy is under revision and the government announced the intention to modify the support scheme for renewable energy (DGEE, 2012). While this includes a necessary adjustment of tariffs for technologies whose costs have substantially decreased, other changes can have a considerable impact on the future evolution of the sector, in particular on the technologies whose diffusion was starting to take-off.

Turning now to situation in the two niches under analysis. **Wind energy** is now widely diffused in Portugal, its deployment taking place mostly through large scale wind plants. The maturity of the technology and extensive government incentives have attracted large investors, national and foreign (including the now privatised utility that created a joint venture specifically for the sector) that are the

[3] The main mechanism is a feed-in tariff. All renewable technologies are eligible, although the amount paid depends on the source, the technology and the system's output and capacity. Energy from renewable sources has priority of access into the grid. Other mechanisms include public financing, public competitive bidding and fiscal incentives. Among these can be mentioned a favourable regime for grid-connected micro-generation.

dominant players. It is possible to suggest that large scale wind generation has broken out of the niche and is decisively entering and competing in the mainstream market, even if its exploitation is still subsidised[4]. However, the implementation of wind systems in Portugal was based on imported technology and therefore local innovation is more likely to be incremental, focusing on organisation and operation systems rather than on core technologies. Opportunities for new technology- intensive companies emerge in the development of technologies that address efficiency, as well as plant and grid level management problems. One of the firms studied offers services in that area.

However the wind sector also presents some developing or emerging segments that are expected to address its current shortcomings (such as intermittence and environmental impacts). One is **offshore wind** that offers greater energy potential, but has a more complex in technology and higher energy costs. Several technological solutions are under experimental development in a field dominated by large international firms. The utility is currently engaged in the development of a new deep-waters offshore technology, in consortium with national and foreign companies, and intends to advance with its commercial exploitation. Since there are strong synergies with wave field (which share the ocean setting and auxiliary technologies) one of wave energy firms in the case studies provides specialised engineering services to both fields. Finally, there are some alternative wind conversion technologies being developed by small technology-intensive firms. One of these is **high altitude wind.** It is a very recent field and both the knowledge about wind behaviour at high altitude and the technologies for capturing power from it are still in a very incipient stage. However, there are a number of companies worldwide developing and testing different types of mechanisms (still at prototype stage). This is the case of one of the companies in the cases studies.

Ocean wave technologies only recently started to move from the R&D to the early stages of industrial development. Technological uncertainty is still very high, since it is not yet established which systems will be more effective in producing electricity while withstanding the ocean conditions. Thus, there are a number of competing systems, which are being tested at experimental settings in various locations (WAVEC, 2009). In this case, it is possible to argue that we are still in presence of a technological niche (Schott and Geels, 2007). A wave energy niche has been very active in Portugal, securing the involvement of some large energy companies and relatively favourable policies (Hamawi and Negro, 2012). Given the good natural conditions (large Atlantic coast and middle climate), the expertise developed by some universities and the proactiveness of local actors, Portugal has emerged as an attractive location for experimental installations promoted by local and foreign companies which, combined with the growing activity in offshore wind, provided some impulse to the niche. Two of the firms in the case studies operate in this field, although with different activities.

[4] It has namely been suggested that it possible to identify "embryonic regime dominated by three-bladed, horizontal axis megawatt-scale wind turbines operating in grid connected clusters and supported through public policy" (Smith et al, 2005).

4.2 The new research-based energy firms

The policy efforts towards the development and dissemination of renewable technologies and the expansion of the renewable energy sector created a favourable environment for the creation of new firms exploiting advanced energy or energy-related technologies, in particular firms originating from university research, whose creation registering a sudden increase in the last years (Fontes et al, 2012). An extensive search conducted by the authors permitted to identify 28 research-based spin-offs developing technologies and systems, that target renewable electricity production and distribution activities[5]. Figure 2 shows their distribution by energy fields. Firms whose technologies are applied in more than one field were assigned to the one corresponding to their main business, unless their activity is transversal. In that case they were included in the “systems and models” group, together with firms offering solutions (methods, instruments and systems) to address system level problems associated with renewable energy production.

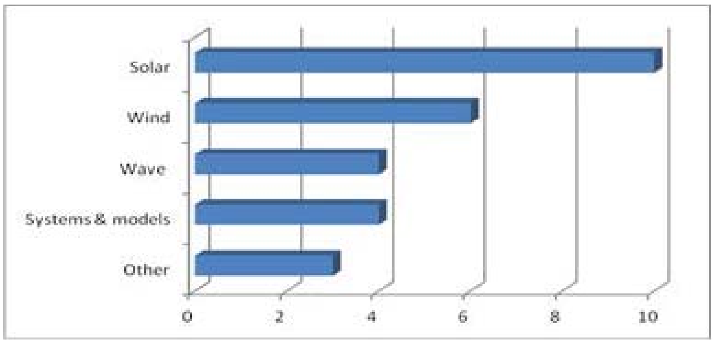

Figure 2 – Research-based spin-offs by application field

The group of firms operating in the wind field are mostly producers of intermediate technologies for the wind farming sector. As pointed out above, the niche is dominated by large companies, largely drawing on imported technologies. Thus, while we still find a small set of firms experimenting with new alternative wind technologies, spin-offs are more frequently involved in the development of technologies to improve the productivity of electricity production from wind sources (e.g. new materials, monitoring and control instrumentation and systems, sophisticated weather assessment or forecast systems). Some of these firms also operate in other areas, besides energy. This contrasts with the activity in the solar field, where most firms are involved in the development of solar systems, namely new generations of photovoltaic technologies (e.g. new types of cells, or building-integrated photovoltaic materials). However, solar spin-off creation started more recently, encouraged by the emergence of a market for grid connected distributed systems, and thus most firms are not yet in the

[5] We have also identified a similar number of new company projects, in different stages of development that were not included in this account, but that reflect the dynamics of the field.

market. Regarding the wave field, despite the preliminary stage of development of the technologies, we still find a small group of spin-offs developing and testing competing equipment and systems.

The firms analysed in this exploratory research were selected from the group of wind and wave spin-offs. The remaining firms identified in these fields will be considered in the next steps of research. Table 1 presents the main characteristics of the firms. Their individual case stories can be found in the Appendix.

Table 1 – Firms* in case studies

	WIND-TECH	OCEAN	WAVE-TECH	WIND-SERV
Year creation	2003	2005	2009	2004
Field	High altitude wind energy conversion (& energy storage)	Solutions in wave energy conversion; Engineering services to off-shore wind	Wave energy conversion	Wind resource assessment (on-shore)
Business	IP development and licensing	Customised development (products); R&D and engineering services	Product development	Plant optimization services based on own methods
Stage of development	R&D	In market with products & services	Prototype	In market with services
Patents	Y	Y	Y	N
Market *(expected)*	Research organization *(Energy producers & distributors)*	Wave energy companies; Off-shore wind companies	*(Energy producers & distributors)*	Wind companies
Team	Young researcher in international organisation	University professors (senior) & industry engineers	Young university graduates	Senior researchers in industry oriented organisation
Incubation	International agency	University	Utility laboratories	No
Capital	Own + Subsidies (European & National RDT Programs)	Own + Subsidies (European & National RDT Programs)	Own + Prizes (Ideas Contests) *(business angels)*	Own + Subsidies National Innovation Programs

* Firms' names are fictitious to guarantee confidentiality

We will now analyse in detail the commercialisation strategies adopted by this group of firms and nature of their interaction with the established energy firms along this process.

4.2 The commercialisation strategies of research-based firms

Drawing on the analytical framework presented in section 3.3 we started by assessing the nature of the technology being introduced and the structure of the energy segment where the firm operates, in order to outline its competitive environment. We subsequently draw on the information obtained from the case studies to understand the firms' positioning concerning the framework dimensions: whether some of the key complementary assets are possessed by incumbents and in which conditions the new firm can gain access to them; whether the technology being introduced by the new firm is relevant for the incumbents and thus which is their attitude towards the technology and its supplier(s); whether the new entrants have the capacity to protect their technology from expropriation.

Regarding the capacity to protect the technology, all firms studied are, at least in principle, in a similar position. In fact, all but one have the core technology protected by patents. The one that did not patent the technology benefits from the protection afforded by the tacit and experiential nature of the knowledge base. It is therefore possible to assume that these firms had conditions to exclude others from imitating their technology. This lowers the risk of appropriation, although not excluding it, given the firms weak capacity to withstand eventual litigation. Thus, at least in principle, firms have better conditions to establish technological and/or market relationships with incumbents (or even to compete with them). We will subsequently discuss the firms' situations regarding the remaining dimensions.

OCEAN and WAVE-TECH, that operate in the wave field, are introducing technologies still in a very immature stage, which require extensive testing, first at prototype and later at pilot stage in real life conditions. These experiments involve complex infrastructures and extensive financial resources that are beyond the reach of a small firm, being often possessed by large firms or consortia that lead large scale demonstration projects. For OCEAN, access to these settings is critical, since it provides a market for its products and services and simultaneously a test bed to improve its technologies. The incumbents show interest in its technologies and are prepared to get involved in its testing and validation. Thus OCEAN has established alliances with the owners of the co-specialised assets. However, because no dominant design has emerged, there are several experimental projects underway. This provides OCEAN with opportunities of cooperation with different partners, the main challenge being to capture their interest in a context where there are several other small suppliers. The fact that OCEAN emerged within the Portuguese "wave energy community" and that its entrepreneurs were actively involved in the early development of the sector was instrumental in this process. The firm benefited from their scientific reputation, industry visibility and extensive contacts to gain access to experimental settings at national and international level. It enabled her to establish a close relationship with local energy incumbents (both the utility and an equipment manufacturer) that have a strategic interest in ocean technologies and provide it with a market for technologies and skills that can be applied both to wave energy and offshore wind. But OCEAN was equally able to establish relationships with foreign companies that lead the wave sector and to participate in consortia involving several public and private actors conducting experimental projects in various countries. Thus OCEAN capitalized on the still turbulent nature of the sector to propose its technology and extensive skills to different partners, deflecting the risks of exclusive relations.

A similar reasoning may apply to WAVE-TECH, which is still developing a prototype, in its future efforts to introduce its innovative wave technology. The main issue in this case concerns the extent to which the new technology being introduced will require the same degree of integration with incumbent assets to obtain a final product, since its system is presented as having a greater autonomy, and also a wider range of applications. In any case, the incumbents' attitude relatively to the technology is likely to be different. Contrary to OCEAN, this firm emerged outside the “wave energy community” with a technology design that departs from the one in which the local incumbents are involved. Nevertheless, we observe an interest of the utility in watching the development of a technology that deviates from its core competence, but appears to have some potential. This is materialised in some contribution to its development (seed capital, access to facilities and human resources), as well as advice and legitimacy. That is, the incumbent is offering access to some key assets that will enable the new company to complete the development of the technology. We observe a strong reliance of the new firm on the “benevolent” interest of the influential company. But its strategy is not confined to the local market. In fact, it profited from the visibility afforded by winning a series of entrepreneurship contests to gain access to an international incubator that is now providing it with a wider range of connections and business opportunities. The firm plans to manufacture its core product and eventually license the technology for other applications (including wind). Once it engages in these activities it will have to make some new decisions regarding the type of relationships to establish.

The case of WIND-TECH, that is also introducing an emerging technology, presents an interesting contrast. First of all, because WIND-TECH opted for focusing on the development of the technology and licensing the intellectual property, thus avoiding the need to build production and commercialisation assets. Second, because high-altitude wind is at an even earlier stage of development, and thus the essential of the relationships WIND-TECH established so far concern R&D activities and are taking place in the context of European RTD consortia (involving public and private organisations). However, subsequent developments may require other types of alliances or, in the limit, licensing contracts. Finally, its technology is much outside the competences of local incumbents. Indeed, the genesis of the company was an international organization in a different field (space) that remains a key partner, being a source of knowledge and contacts. However, the utility integrates the RTD consortium, denoting some interest in keeping a watch on a technology that is a potential extension - or even a competitor – to its core wind area.

Finally, the structure of relationships is clearly different in the case of WIND-SERV that operates in the onshore wind segment, dominated by large incumbents. In this case the new firm is a typical small specialised supplier of services that improve the performance of the incumbents’ core business. Thus, its activities provide value to the incumbents, but competition with them is unlikely given the different set of competences involved, and the risk of expropriation is low because imitation is difficult. Although the firm business depends on the incumbents’ activity, it sells its competences in a market populated by a variety of potential clients and thus arms’ length commercial relationships prevail. But long standing relationships exist with important clients, some of whom had a lead-user role at early stages and have consistently included the firm in their wind plant installation projects.

Table 2 – Factors shaping commercialisation strategies

		WIND-TECH	OCEAN	WAVE TECH	WIND-SERV
		R&D *(technology)*	**Services & products** (customised)	**Prototype** *(product)*	**Services** (plant optimisation)
Background	**Stage of development of technology / energy segment**	Emerging field: no dominant design. Early stage (prototypes)	Emerging field: no dominant design. Experimental projects.		Stabilised technology / large scale systems with efficiency and reliability problems:
	Opportunities for research-based entrants	Early development of new conversion systems (publicly funded)	Development of new conversion systems. Offer technologies/services to organisations involved in or managing experimental projects. Synergies with offshore wind (shared technologies)		Scope for suppliers of solutions (plant and system interface management & support systems)
Commercialisation environment	**Firm capacity to protect technology**	**Patented**	**Patented** (+ firm specific knowledge)	**Patented**	**Firm-specific & experiencial knowledge**
	Relevance of CAs possessed by incumbents and firm access to these assets	Knowledge distributed by several organisations (R&D consortia)	Complex infrastructures & financial resources required; integration in large systems: *CAs controlled by incumbents* (even more in offshore wind)	*Idem*: But new technology design, that may not require same degree of integration with incumbents assets	Specialised supplier of services that improve incumbent performance: final clients but *no dependence on co-specialised incumbent CAs*
	Incumbents attitude to firms' technology	Incumbents follow-up the new technology through participation in R&D project led by firm	Incumbents interested in technology: experimental projects as test-bed & market	Incumbents interested to closely watch the development of the technology (support prototype development)	Incumbents interested in using technology (incorporate in process); Scope for project-based relations in foreign market entry
Types of incumbents and their actual involvement with firm		**Utility** & **Foreign firms:** watchers	**Utility & equipment producer; Foreign firms**: partners & clients	**Utility:** watcher *(Firms is prospecting foreign markets)*	**Utility, new players, foreign firms**: clients
Strategy adopted by new firm		**Sell technology**	**Alliances required to enter market**	**Alliances may be required to enter market**	**Enter market directly with service:** arms-length market relations, some long-standing associations

WIND-SERV early expansion to foreign markets also benefited from the interest of the incumbents in the technology, since it often took place in the context of their international projects. This was instrumental for its penetration in some foreign markets. The firm also draws visibility from the consistent participation of its entrepreneurs in activities for the promotion of the industry

Table 2 summarises the above analysis, presenting the situation of each firm in terms of the factors shaping its commercialisation strategy, as proposed in the framework. This analysis enables us to uncover some sources of variation in the conditions experienced by firms, that can at least partly explain their positioning relatively to incumbents and thus the nature of the relationships established with them in the commercialisation process. Drawing on it, we can position the firms along the main dimensions of the "competitive environment", as defined by our framework (Table 3).

Table 3 – Positioning of case study firms and types of relationships established

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="3">Relevance of complementary assets possessed by incumbents:
Firm access to complementary assets</td></tr>
<tr><td>Access in market</td><td>Controlled by incumbents</td><td>Skip (sell technology)</td></tr>
<tr><td rowspan="4">Relevance of technology for incumbents:
Incumbent attitude</td><td>Watcher</td><td></td><td>WAVE-TECH
(Wave conversion)
Alternative technology design developed outside "wave community".
Support to new firm as monitoring device</td><td>WIND-TECH
(High altitude wind)
Alternative conversion technology that deviates from incumbents' core competence & operational control.
R&D alliances as sources of potential clients for technology</td></tr>
<tr><td rowspan="2">Interested in development</td><td rowspan="2"></td><td>OCEAN
(Wave conversion;
Offshore wind engineering)
Wave technology design developed jointly in local "wave community"
Offshore: technology adds value to incumbents assets and is used by them
Alliances combining technology and market elements</td><td rowspan="2"></td></tr>
<tr><td>WIND-SERV
(Wind plant optimization)
Technology that adds value to incumbents assets and is used by them
Market relations, but some longstanding alliances with lead-users</td></tr>
<tr><td>Competitor</td><td></td><td></td><td></td></tr>
</table>

Considering the generic commercialisation environments proposed by Gans and Stern (2003), it is possible to conclude that the “ideas factory” type of competitive environment appear to prevail in the energy fields analysed, although we observe at least one emerging technology that has potential to operate outside the centralised regime favoured by incumbents (high-altitude wind) and thus offer different conditions. But the case studies also permitted to go in greater depth into the nature of the relationships that are associated with different positioning of the new firms relative to incumbents and different attitudes of the later.

In both fields, the new firms depend more or less clearly on the complementary assets possessed by large energy incumbents, although the analysis enables us to understand that this happens for different reasons and assumes different forms, depending on the nature of the niche and also on the technology. In wind, this results from a combination of incumbents’ dominant position in the industry and interest in the complementary technologies that add value to their assets. This is valid for both onshore and offshore, because despite the less mature stage of the technology in the latter, the relative position and function of the two actors is similar. Thus, new firms act as specialised technology suppliers to incumbents, establishing market relationships with them, which are more arms-length in onshore given the maturity of the technology and the larger number of customers. But we observe, in both cases, the presence of closer, longstanding relations with an important role in the early market introduction of the technology (in onshore) or in the access to service opportunities (in offshore).

In wave, where a dominant design has not yet emerged, relationships derive from the strong interest and resulting positioning of a number of incumbents in the emerging field. Thus, the new firms develop the conversion technologies, but incumbents have a dominant position in what concerns the access resources and infrastructures required for test and demonstration. They are also well positioned to influence the development trajectories of the technologies, so that they match their operational competences and knowledge base, as well as to come to control the final installations, may that require important investments. The nature of relationships depends on the degree of incumbents’ familiarity with the technology: close, longstanding relationships when they were involved in the development of a given design vs. monitoring of alternative designs, through the identification and early support of new companies introducing them. Their future involvement may nevertheless be influenced by the developments taking place in offshore wind, since competition for attention and resources between the two ocean energy technologies may end-up having a negative impact on the less mature one: wave.

Despite the small number of cases, it is possible conclude that in the energy fields being analysed there is some incumbents’ interest in the new technologies, and even some involvement in their development and use. On the other hand, the incumbents' attitude appears to be beneficial for the early activity of the new firms, providing resources, markets and legitimacy, even if this sometimes entail some deviations from the initial trajectory to adapt to incumbents' interests. It also implies a great dependency on powerful companies, which is stronger when the number of incumbents involved in the field or interested in the technology is smaller, as becomes particularly evident in the case of wave energy. Indeed, new firms operating in this field search for partnerships with foreign companies, which can offer greater scope for exploitation and limit the threat of excessive dependence on one large partner.

5. Conclusions

This paper investigated the strategies open to new research-based firms introducing advanced renewable energy technologies in the Portuguese electricity production sector. Since the sector combines a strong incumbent power with fast technological development, it emerged as particularly interesting for investigating the new firms' positioning relative to large established companies and the attitudes of the latter towards their technology, thus providing some insights into the nature of the business-level interactions between niche and regime actors.

An analytical framework was developed and tested on the basis of case studies in two niches in different stages of development, but where there is evidence of incumbents' involvement - wind and wave energy. The research presented in this paper, although still preliminary, permitted an in-depth analysis of the strategies adopted by the new firms and provided some insights into the behaviour of incumbents in these fields. These first results suggest that both fields are characterised by a competitive environment where: new research-based firms tend to depend, to a greater or lesser extent, on the downstream complementary assets possessed by large energy incumbents (unless they opt for selling the technology), but have the conditions to protect their technology from appropriation (mostly with patents); and where the new technologies are relevant for (at least some of) the incumbents, which show interest in their development, although through different levels of involvement. This is conducive to "cooperation strategies", but these can assume diverse forms, depending on the stage of development of the niche, the maturity of the actual technology being exploited by the new firms and its proximity to the incumbents' knowledge base and operational competences.

These preliminary results confirm the usefulness of the analytical framework proposed to address the strategic behaviour of niche innovators in this type of context and offer some first insights into how firms act to introduce their technologies; how they interact with one crucial element of the system to access and deploy key resources; and how the conditions faced on their particular competitive environment influence their potentially disruptive behaviour. This adds to recent research on transitions that address the micro-level analysis of the strategies of individual entrepreneurs (Alkemade et al, 2011; Avdeitchikova and Coenen, 2013) and their interaction with other elements of the system (Musiolik and Markard, 2011), extending and complementing the extensive body of research focusing on system level mechanisms and dynamics (Markard et al, 2012).

The results are consistent with the literature that discusses niche evolution as involving processes of linking-up with developments taking place within the regime and that argues that these processes assume different forms in different types of niches (Schot and Geels, 2007). They also reflect processes of hybridisation (Raven, 2007) whereby niche technologies are partly adapted to match incumbents competences and interests. Although this may preclude more radical transformations, and result in the new approaches being captured by the regime, it may also lead to some changes (albeit slower) in the regime configuration (Verbong and Geels, 2010). In fact, in the case of a complex infrastructural system such as the energy/electricity production, it can also be a strategy through which niche innovators profit from regime tensions – such as the ones already induced by renewable energy – to "infiltrate" their novel technologies and practices, translating them into ways acceptable by regime actors (Smith, 2007) and simultaneously gaining them to support niche development.

In the cases discussed, some incumbents were perceived by the new firms (and other niche actors) as an important element in the development of the niche – profiting from the favourable policies, but in any case driving some of the technological and market developments taking place. They become also critical element at a time of declining incentives, if niche actors are able to maintain their alignment with niche interests. This appears to confirm the idea that presence and interest of incumbents can bring-in resources and legitimacy and reinforce the development of supportive networks … at least up to a point. In fact, the strong involvement of incumbents that was identified in the niches analysed also raises a number of questions regarding the actual nature of their interests, as well on the impact that their "insider" intervention may have in the definition of policies, in the trajectory of the niche technologies and, more generally, on the behaviour of other niche actors (Smink et al, 2011). Since, regime interest is always likely to "provoke a niche reconfiguration closer to the regime" (Smith, 2007: 447) it may be important to investigate in greater detail the impact of regime actors´ involvement on the behaviour new firms operating in the niche and on the outcome of their innovative activities.

Thus, subsequent research will expand these results, by applying the framework to a larger number of cases along the different categories considered, in order to verify whether these preliminary results are confirmed and also to achieve a more precise understanding of the processes underway as part of the interaction between the various actors. It will also be relevant to extend the analysis to other energy niches that have so far raised a lower interest on the part of regime incumbents. This is namely the case of solar energy, that displays a less centralised development trajectory and, thus, where competitive environment may differ, leading to potentially different and strategies and modes of interaction.

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Appendix – Case stories

OCEAN

OCEAN is an engineering company, created in 2005, that offers a range of solutions in the field of wave energy, from project management to systems design and supply chain development, including operation and maintenance. The firm specialises in the OWC (Oscillating Water Column) technology and has developed a number of technologies in this field. These technologies are the basis for the firm core activity: the conception and development of customised systems.

OCEAN was created by a team that put together scientists with a longstanding experience in hydropower and wave energy - who were among the pioneers of the wave field in Portugal - and engineers with previous experience in engineering companies. The group of scientists had been involved in one of the first experimental projects for the installation of wave energy system: the Pico Pilot Plant in the Azores islands (Portugal). This involvement was the driver for the subsequent creation of a firm that developed project-related and system maintenance service activities, first to the Pico Plant and later for other projects, in Portugal and abroad. In addition to the specialised service activities, the firm also started developing its own technologies, in collaboration with universities, including the university of origin of the scientists (who maintained their jobs). These technologies have been patented and customised products have already been developed for clients involved in the installation of experimental systems, in Portugal and abroad. More recently the expertise gained in the conception and installation of ocean systems enabled the firm to extend its activities to the offshore wind energy production, through the participation in an experimental project in this field. Both the research that led to the development of firm's technologies and the experimental projects in which it participates, have been funded by national and European programmes, often involving academic and industrial partners.

The dual origin of the entrepreneurs provided the new firm with different sets of competences (science, engineering, management) and also with different sets of networks. The scientists' networks were critical for the establishment of formal relationships with universities, enabling access to laboratories, equipments and human resources, besides permitting the informal access to new knowledge. They equally facilitated the integration in European research projects, which provide both funds for research and international contacts. On the other hand, the experimental background of the scientific team provided them with hands-on experience in the implementation of actual projects and longitudinal data on their functioning. It also permitted them to establish relationships with other key actors in the Portuguese wave energy milieu, in particular the Portuguese energy utility and a large energy equipment producer. These were involved in the Azores experimental plant and maintained an interest in the field, participating in other projects and being currently involved in the launch of a Pilot Zone for wave energy systems. The entry into this network was also critical for the expansion of the firm's activities to offshore wind projects, where these same actors are involved.

On the other hand, research networks together with the extensive contacts established by the non-academic elements in engineering firms, were instrumental for the participation of the firm in experimental projects being launched in other countries (in particular the UK and Ireland). Given the stage of development of the field, integration in networks that grant access to experimental or demonstration projects is critical, since these are the sole market for a small supplier of technologies and services and also provides a test-bed for the technologies it is developing. The non-academic group adds its strong engineering experience that is critical for the practical aspects of project management and product development. It is also responsible for the concretization of the commercial opportunities – where both their previous experience and their networks and individual reputation are instrumental.

The firm and some of its entrepreneurs at an individual level, have been consistently involved in the promotion of ocean energy at country level, both in the research domain and in the coordination of technology development and political lobbying efforts. They were namely active in the creation of a dedicated technology centre that involves universities and several companies active in the field.

WAVE-TECH

WAVE-TECH is a recent start-up, created in 2009, that has developed and patented a new and more efficient process for transforming kinetic energy into electricity: an Electric Spherical Generator (ESG). The characteristics of the system (compact and adaptable to any size) made it suitable for different market applications. It was decided to initially focus on the wave energy field, where the system emerged as particularly effective and competitive with existing solutions. A product is currently being developed (prototype stage): a floating structure for capturing energy from waves, having the ESC at its core, which is also patented.

The process of WAVE-TECH formation is substantially different from that of OCEAN. It was created by a team of young university students from different fields (mechanical and electrical engineering and management) whose objective was to develop a more efficient system for converting movement into electricity, initially conceived to be a charger for small electronic equipments. Thus, the starting point was not the wave energy field. It was only after they developed a first small generator and won a number of entrepreneurship and business ideas contests that the opportunity to apply it to wave energy production arose. The technology was then reconfigured in order to answer to the harsh demands of the new application field. Regarding the new application, the turning point was the 1st place in the innovation contest promoted by the energy utility, that provided a financial prize to support the creation of a start-up company and the technical development of the project, and also included technical support from the utility own laboratories. This prize was critical for the new firm, since it brought its technology to the attention of the energy utility, which has a great interest in ocean energy technologies, thus facilitating subsequent access to testing facilities and to the local market for wave energy projects.

Thus, the definition of the actual market opportunity to be exploited was a process that received important contributions from experienced researchers from the universities of origin of the entrepreneurs (who currently compose the scientific advisory board), as well as from a technology transfer organization in the wave energy field and from the energy utility. The development and first tests of the wave energy system took place in close collaboration with the same organizations. The young team was thus able to compensate for the absence of business experience and the limited research background of its members by developing relationships with relevant academic and business players.

The ability to congregate a variety of competences around this project was largely due to innovative nature and unique characteristics of the technology, which were recognized in a variety of business idea and innovation contests where the company obtained first prizes. This draw the attention of the media, creating “a buzz” around the technology that was used by the entrepreneurs to raise the interest of the market and potential partners. These contests were also an important source of seed capital and provided additional resources such as business training/tutorials. As a result of one of these contests the company was invited to spend a period at a technology incubator located in Silicon Valley. This stay was supported by a large supplier of energy equipment not yet operating in the wave field, which may have regarded this association as a way into it. The company regards this stay as providing the opportunity for a wider diffusion of its technology and for expanding its international network of contacts among potential clients. In fact, its goal is to produce and sell the wave energy generator worldwide. On the other hand, it is aware of the wide potential of its core technology – the ESG – and is planning to license it to other potential markets.

WIND-TECH

WIND-TECH, created in 2003, operates in two main fields: aerospace technologies and energy systems. Regarding the energy business it defines it as focusing on energy conversion systems and is currently operating in two main fields: energy and gas storage and high altitude wind conversion. The dual focus aerospace/energy is relatively unusual, but has a relevant impact on the activities conducted in the energy field. In fact, the technologies being developed combine knowledge of airborne structures and unconventional means of propulsion, with energy transfer forms. The firm is focused on upstream technological development with a view to producing intellectual property assets that will subsequently be licensed to other organisations.

The firm originated from aerospace research – its founder worked in the European Space Research and Technology Centre (part of the European Space Agency - ESA), where the firm was initially incubated. The entrepreneur decided to establish the company in his home country and upon returning to Portugal benefited from the support of a number of Portuguese universities and research centres that provided a second incubation environment, granting access to their laboratories and equipment and also providing human resources.

WIND-TECH early activity was on areas related with the entrepreneur research at ESA, having this organization as the main partner and also as client. Thus space-driven technologies, in particular those related to the storage area, were the first focus, resulting in a number of patents. The space industry is currently the main market, with particular relevance for ESA which remains a key client and an important source of industrial contacts. The activities conducted in this area may in the future also have some potential for other types of market, such as the automotive industry (CO2 storage/recycling) or other sectors seeking advanced gas storage solutions.

However, research was also conducted in the field of high altitude wind and this area has recently become a flagstone of the company. Partly drawing from the knowledge and competences developed in the space field, WIND-TECH conceived and patented a new system that can capture energy from very low altitude wind, using the aerodynamic forces acting upon an airborne craft. Research is currently on-going, funded both by national sources and by the 7FP. The latter is led by WIND-TECH and involves collaboration with Portuguese and European research organizations as well as industrial partners, including the privatised energy utility. High altitude wind conversion still faces a number of complex technological challenges, but the firm believes that the concept under development can put them at the forefront of this new field.

WIND-SERV

WIND-SERV, created in 2004, is a consultancy company that specialises in wind resource assessment services, based on advanced wind modelling techniques. It offers a range of services from site evaluation to wind resource assessment studies, including planning, wind measurement campaigns and project due-diligence. The company also started providing consultancy in other renewable energies where its assessment competences are also applicable (e.g. large solar power plants), although this business has a much smaller weight.

WIND-SERV was created by a team of senior university researchers with extensive experience in the wind field. Previously to creating the company they combined their academic activity with research and managerial activities in a research and technology transfer organisation that has been actively involved in the development of the Portuguese wind industry, from its inception. The exposure to the industry's activity enabled them to identify a market for this type of services and to anticipate its growth, given the expected expansion of wind power plant installation. The low career expectation at the university (given the precarious positions occupied) further encouraged the members of the team to pursue with this project. Two of the entrepreneurs had a MBA and one had had previous business management responsibilities at the parent organisation, which provided the team with a reasonable set of managerial competences.

However, the creation of the new company was regarded with some hostility by the parent organisation (which earns a considerable amount from consultancy work). Therefore subsequent R&D activities were conducted in collaboration with other organisations, although informal connections were maintained with some colleagues. The collaboration with two Portuguese universities led to the development of more sophisticated wind assessment techniques such as mesoscale modelling and computational fluid dynamics (CFD) simulations, which put WIND-SERV at the forefront in its field. The firm was installed in a S&T park associated with the university.

The contacts established by the entrepreneurs with the firms involved in the early wind energy projects facilitated access to the main players in the industry (both already operating in the energy sector and new entrants to the business) and enabled WIND-SERV to become a key partner to energy producers, equipment manufacturers and plant installers. The entrepreneurs were also actively involved in the promotion of renewable energies at country level and become members of national and international trade associations of the sector. This positioning and contacts also enabled the firm to develop an international reputation and to start internationalising its activities, both for Europe (namely Eastern Europe) and for Brazil and Portuguese speaking countries in Africa, where subsidiaries have been created.

Submission No. 319

Socio-ecological transitions of cities
Exploring spatial, ecological and governance dynamics in European cities

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Abstract

Europe is in general in a good position for examining dynamics and potential for realizing a positive transition to resilient and sustainable urban areas. Compared to most other continents, the living standards are good, the decision making processes are fairly open and transparent, and the level of knowledge including environmental knowledge is relatively high. We examine five compact cities to unravel what drives their social-ecological transition to resilient urban futures. A meta-analysis of spatial, ecological and governance dynamics reveals that in the face of slow urbanization the European compact cities under study undergo a transition towards eco-city that is the result of five co-evolving drivers: (a) the presence and implantation of strong environmental policy at local and regional level that promotes the preservation of existing green spaces; (b) the capitalizing of governance capacity for urban sustainability in the form of setting urban green plans and deals; (c) the restoration and re-establishment of green urban spaces of different sizes in the cities or simply, creating more green spaces (d) the put forth of green strategies and actions from multiple policy centers and (e) the emerging social niches of community gardens and urban agriculture that restore green in the cities and take over empty or unused spaces. These drivers do not play alone but are stressed with challenges of fair distribution of green in the city and of slow responding policy and governance.

Keywords: socio-ecological transitions, cities, green infrastructure, resilience, ecosystem services

1. Introduction

Cities are cradles for innovation and sustainability transitions (Grim et al, 2008; Ernston et al 2010; Truffer and Coenen, 2012). Cities are places where slow and fast transitions are initiated and accelerated as well as test-beds and seedbeds for innovations (Hodson and Marvin, 2010; Scott-Cato and Hillier, 2010; Bilkeley and Broto, 2012). Cities have social, ecological and technological assets that are essential for economic and social development; there is thus an imperative for balancing their strive for continuity and prosperity while ensuring a sustainable livable space for citizens to live in. Increasing policy attention is put on the processes of change that take place in cities and for cities to drive the way to livability and resilience. This shows the diversity of opportunities and conditions in cities, where challenges such as urbanization and globalization contribute to the pressure for rerouting current development pathways to sustainability and resilience. Urban studies scholarship offers insights about how pressures of globalization and urbanization may affect current livability standards in cities (Seto et al 2012; Buhaug and Urdal, 2013) and also problematize on the implications of an abrupt transition of cities due to unpreparedness in face of climate change, demographic changes, ageing and a cascade of financial crashes (Neeraj et al, 2009; Romero-Lankao et al 2012).

In transition studies, cities have so far served as the new case beds for exploring potential and dynamics of socio-technological transitions (Hodson and Marvin, 2010; Bulkeley, 2010; Geels 2011; Truffer and Coenen, 2012; Coenen et al 2012; Smith and Wiek, 2012; Spath and Rohracher, 2012). There is however another transformation current in place in different cities: an ecological transformation of cities that is realized either via policy programs for conserving or restoring urban ecosystems or via emerging initiatives for greening the city and restoring urban ecosystems (Pickett et al 2001; Hammer et al 2011).

We adopt a social-ecological approach to research and understand urban transitions. Such perspective has been lacking in both urban studies and transition studies. Even though urban studies have problematized and re-conceptualised ecosystem approaches, the ecosystem-oriented urban scholarship focused on translating the ecosystem principles to design and evaluation of urban space rather than explaining its transformation over time (Newman, 1999, van Bueren 2009; van Bohemen, 2012; Beatley, 2011; 2012; Yang, 2013; Platt et al 1994; Stokols et al 2013). More specifically, we argue that conceptualizing cities as socio-ecological systems serves to understand what (metabolic) characteristics are required for sustaining urban ecosystems that will in turn provide ecosystem services that benefit the health of the urban citizens as well as increase the adaptive capacity of cities to deal with climatic pressures and extremes, ageing population and other demographic shifts as well as socio-economic clashes. Considering urban ecosystems as of vital importance for the resilience of urban areas implies a shift in the way cities are sustained, maintained, governed and change (Ernston et al 2010; Pelling, and Manuel-Navarrete, 2011).

A social-ecological perspective for cities

Scholarship of social ecological systems and resilience approach long examined the dynamics of coupled social ecological systems (Carpenter et al, 2001; Walker et al 2002, 2004; Folke and Gunderson, 2013,). Based on their research and experience, a perspective on socio-ecological systems has been formed. The social-ecological systems' perspective includes some core conceptualizations around the coupled system that guide the understanding of its transitions:

- society and ecosystems are coupled and interdependent – meaning that changes in one system inflict changes in the other system and visa versa not of linear relation given that are complex adaptive systems
- interactions in such a coupled system do not resemble simple cause-effect relations but connect via feedback loops that create cumulative or dampening effects
- social-ecological systems' perspective posits systems at dynamic equilibria and the passage/shift from one dynamic equilibrium to another can be streamed by the action of attractors that can push a system to a new basin of equilibrium.

Social ecological systems are thus striving for balanced interaction that is achieved by transforming and adaptive in such a way that resilience is maintained and in this recurring adaptation and transformation processes sustainability is achieved (Frantzeskaki et al 2010). A conceptual and analytical strength of the social-ecological perspective is the high level of aggregation in examining the dynamics of the coupled system that is resembles long-term dynamics and the rich empirical ground from which it draws of historical shifts in ecosystems (Scheffer and Carpenter, 2003; Beier et al, 2009; Crepin et al 2012; Knoot et al 2010). A conceptual and theoretical weakness of this approach is that social dynamics are (often) investigated using the transferability principle: ecological processes can be used as conceptual frames to explain social processes (i.e. Golubiewski, 2012). Nonetheless, the social-ecological perspective offers a strong basis for understanding dynamics and system shifts. A social ecological system's perspective for urban sustainability includes that cities are understood as coupled systems in which ecosystems (either natural or restored or planned/designated) of and in the urban context are vital and equally important for the city's resilience and on the long-term its sustainability. This perspective comes in contrast with the dominant perception that cities are social-technical systems or simply the build environment with dominant socio-technical dynamics.

Early research on sustainability transitions and their dynamics also acknowledges social-ecological transitions as a strand of coevolutionary processes that build up to a broader societal transition to sustainability. Kowalski-Fisher and Rotmans (2009) in their early paper argue that there is a complementary understanding of transformations in social-ecological systems: the metabolic paradigm of change with its introvert perspective on change explains systemic processes but neglects surprising innovations that come from 'the outside' (with main expressers being Fischer-Kowalski and Haberl, 2007; Krausman and Haberl, 2007; Krausman, et al 2008) and the transitions perspective that positions drivers of change outside the system acting as triggers and often being innovations of high-potential for rerouting the system towards greater levels of sustainability (Rotmans et al, 2001). Both perspectives offer ground for explaining social-ecological transitions taking societal dynamics into account.

Recent experiences and practices in cities show that cities strive to restore or create urban green in vacant areas, in brownfields and in impermeable areas not only for amenity reasons but also for employing natural elements to achieve safety goals in the cities (Jim, 2004; O'Neill and Abson, 2009; Lehmann, 2010; Sassen and Dotan, 2011). Momentum was gained with the TEEB approach (2010) that proposed that ecological/biotic features in cities can benefit society in multiple ways: they can regulate climatic conditions and in this way regulate and repulse local (often addressed as micro-) climate, they can provide food, substances for medical uses and they can also contribute to amenity and comfort by simply being the places for people to connect to nature, to relax, and to have a different experience. As such recent research investigates what are the potential provisioned benefits of ecosystems situated in cities regardless their naturalness or size.

A social-ecological transitions' perspective for cities: A proposition

A sustainability transition is defined as a process of fundamental change of cultures, structures and practices that involved multiple actors, takes long time to materialize (over a generation) and is progressive in its nature resulting from build up of small-scale incremental steps both emergent and planned (Rotmans et al, 2001; Frantzeskaki and de Haan, 2009; Frantzeskaki et al, 2012). From a transitions perspective, cities undergo co-evolutionary processes of change that progressively build to a fundamental shift in cultures, structures and practices. Urban transformations from a transitions perspective are seen as the outcome of multiple interconnected processes that evolve and co-evolve over time. Urban transitions are thus outcomes of confluence of multiple dynamics (Frantzeskaki 2011, Frantzeskaki and Grin, 2012, Nevens et al 2013).

2. Research approach

2.1 Research objective and research questions

The main research question that we seek to address is the following: *What are the dynamics of socio-ecological transitions of European cities?* For addressing the research question we will investigate the following process drivers in different European cities:

- What are the ***common drivers*** evinced in land-use changes and form of the urban geography in (the case study) European cities?
- What are the ***common drivers*** evinced in the policy and planning processes that can influence a socio-ecological transition in (the case study) European cities?
- What are the ***challenges*** beyond land use change that cities face for a socio-ecological transition to green resilient futures?

2.2 Research locations

Europe is in general in a good position for examining dynamics and potential for realising a positive transition to resilient and sustainable urban areas. Compared to most other continents, the living standards are good, the decision-making processes are fairly open and transparent, and the level of knowledge including environmental knowledge is relatively high. European demographics, though, i.e. ageing populations, represent a challenge to innovative socio-ecological transitions.

The paper builds on case study research in five European cities of diverse sizes (from small-size to large-size) that have two common characteristics: a) all cities show no increase of their spatial boundary over the past 10 years – they are not expanding nor sprawling-, and are characterized as compact cities and b) all cities have a planning and governance system for urban green and blue infrastructure in place that now faces new urban challenges. The case study cities include: Barcelona in Spain, Berlin in Germany, Rotterdam in the Netherlands, Salzburg in Austria, and Stockholm in Sweden (Figure 1).

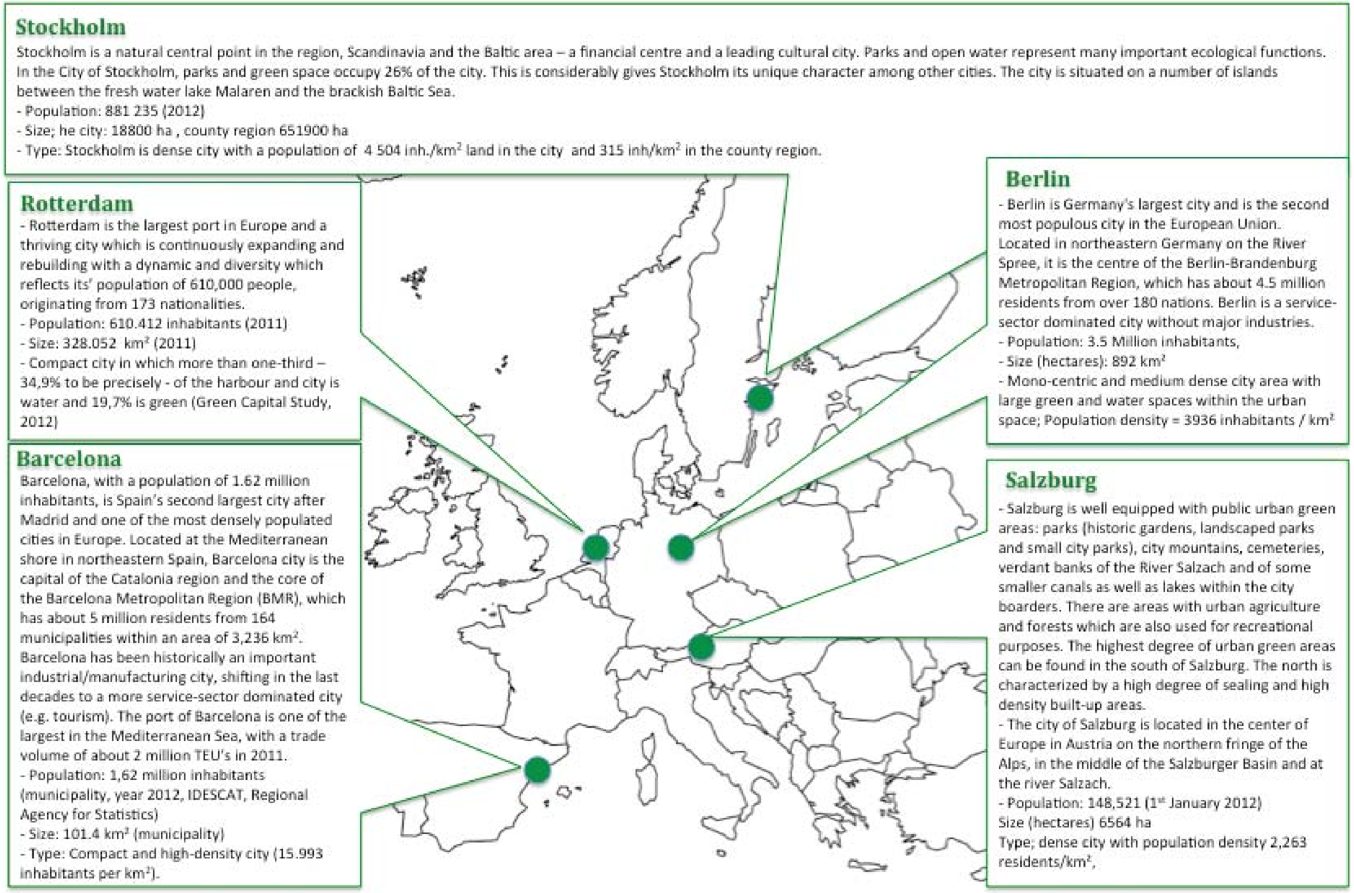
2.3 Research methods

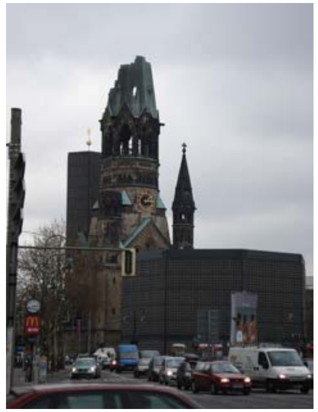
In each case study, a multi-method approach has been adopted and as such, different methods employed to harvest data and to triangulate findings. For analyzing the data, we used meta-analysis method with template analysis (Glass et al 1984). Meta-analysis is a deductive approach suitable to identify common patterns (in the form of drivers, processes, paradoxes or tensions). In our paper, we analyze multiple cases with template analysis to deduce common patterns of transition dynamics along three dimensions: spatial, ecological and governance dynamics. Our methodology complies with the approach of Glass et al (1984) that argues that a smaller number of extensive cases suffice for a verifiable meta-analysis construction. For data validation, in every case study different methods again have been employed to better harvest data from the different socio-political contexts (Table 1).

View of Stockholm’s parks, Sweden

View of Rotterdam, the Netherlands

View of Rotterdam, the Netherlands





View of Berlin, Germany

Figure 1: An information map of the case study cities including view images of the cities (pictures are author’s owned).

Table 1: Data collection and validation methods for every case study.

Case study city	Data Collection for *Spatial and Socio-ecological dynamics (including governance dynamics)*	Data Validation *for findings and analysis*
Barcelona	- Statistical data (census, green space, environmental indicators) obtained from the City Council and Regional Agency for Statistics, IDESCAT (2012) - Ecological Map and land-use map of Barcelona obtained from the Barcelona City Council and CREAF (Centre for Ecological Research and Forestry Applications) - Review of urban development and urban strategic planning and management documents from "Urban habitat" ("Hàbitat urbà") department of the City Council - Field data observations in 332 plots with vegetation following i-Tree Eco model protocols (May to July 2009) - Questionnaire surveys to Montjuïc urban park beneficiaries (N=198) (May 2012)	- Validation of findings and analysis by 18 in-depth interviews with local experts and practitioners from various disciplines (ecology, urban planning, history, medicine, etc.) and institutions (local and regional authorities, public agencies, academia, NGOs) (April-July 2012)
Berlin	- Statistical and census data obtained from the City and Regional Agency for Statistics (2012) - CORINE Land-use data (2011) and Urban Atlas database (2012) obtained from European Environmental Agency (EEA) - Review of planning documents from Local Planning Authority of Berlin (German: Senatsverwaltung) and GRÜNBerlin GmbH (2012) - Questionnaire surveys, interviews and observations in 2011 and 2012	- Validation of findings and verbal review of them via expert consultations (5 individuals) (April 2013) (on-going)
Salzburg	- Landuse change modeling to recover the green space changes over the past 20 years - Extensive review of policy and planning documents (January 2012-February 2013) - Review of demographic statistics and databases on land use changes with a time spam of 10 years (February-April 2013)	
Stockholm	- Statistical data from Statistical Yearbook 2013 of Stockholm (www.statistikomstockholm.se) - Extensive review of policy and planning documents (November 2012-March 2013) - 10 in-depth in person interview with policy stakeholders and experts including city and regional planners, strategists, ecologists, NGOs, architects, managers in construction companies and researchers (conducted in December 2012-March 2013).	- Stakeholder workshop (16 individuals) with urban planners, corporate actors, scientists, consultants and architects from Stockholm on a working session to verify current situation and its driving trends (April 2013)
Rotterdam	- System analysis using the Green Capital City Indicators and Fields of analysis - Review of policy documents, documents and reports of urban planning programs and visions and legally binding strategic programs (>60 documents) - 17 interviews with policy stakeholders with 10-15 years experience in city's policy and planning (conducted in September 2011-March 2013) - 2 interviews with change agents of the city that initiated urban agriculture projects (conducted in September 2012) - 3 interviews with ecologists of the City's Ecology Office (October 2011 and September 2012)	- Expert Focus Group (6 individuals) of academics and consultants working on projects for urban sustainability in Rotterdam city for more than 5 years reviewed the current situation dynamics (April 2013) - Stakeholder workshop (10 individuals) with urban planners from different levels within the Rotterdam Municipality on working session to verify the socio-ecological drivers and patterns for Rotterdam city's urban green and blue infrastructure (April 2013)

3. Social-Ecological Transition Dynamics of European Cities

3.1 Spatial Dynamics

The meta-analysis of cities shows that current land use changes in cities do not dramatically alter the spatial fabric and area coverage of the case study cities. ***Urbanization is a slow driver of change in the five selected European cities.*** The drastic changes to the urban landscape in European cities realized by early 1990s, have ***no successor changes, creating a rather unchanged urban boundary and build environment the past 30 years*** (Figures 2 and 3). The changes that are emerging or on-going concern renovations, restorations and restructuring of existing areas into more sustainable areas without expanding outwards or drastically altering existing land uses (Haase 2008). Does this imply that cities do not change? On the contrary, cities are facing a slow transition where different demands have to be met and landuse changes are marginal but nonetheless important for the city's social-ecological transition (Nuissl et al, 2009).

A city that experienced a drastic transition in 1990s and a slow transition ever since is Barcelona. The Olympic games of 1992 substantially transformed the urban structure of Barcelona. For example, the former industrial district of "Sant Martí" was mainly changed to residential and commercial space. The district was "opened" to the sea, creating a long esplanade next to the beach shore. The main sport facilities for the Olympics were built in the urban park of Montjuïc, notably transforming this largest inner-city green space of Barcelona. The city has experienced other important spatial changes in the past years with much lesser socio-ecological impact, such as the transformation linked to the Universal Forum of Cultures event in the North costal area of the city in 2004. In the last three decades, the city has experienced a process of densification, since urban expansion is physically very limited (the city is surrounded by the sea, the mountain range of Collserola and by other municipalities of its metropolitan region) and economic pressures over land have been very important (e.g. housing demand). According to the spatial dynamics observed from the Ecological Maps of Barcelona (1977, 1993 and 2004; Burriel et al, 2006) the high-density built-up land uses (both residential and commercial) have increased, mainly at the expense of agricultural land (nowadays nearly inexistent within the municipality), vacant lots and low-density built-up land uses. However, the urban green space (mainly inner parks and gardens) and the natural green space (mainly Collserola Natural Park) would have slightly increased in the last decades.

Berlin is the European city that experienced with the most drastic historical transition. The societal and political transition in 1990s with the fall of the Berlin wall was followed by a rapid economic change, closure of industries and outflow of population to the western part of Germany. In June 1991, the German Parliament, the Bundestag, voted the "Hauptstadtbeschluss" to move the seat of the (West) German capital back from Bonn to Berlin, which was completed in 1999. Since then a large influx of people working in administration and science to Berlin, transforming city's economy into a service economy. At the same time, Berlin developed into of those cities in Germany with very high poverty rates. The unemployment rate reached a 15-year low in September 2011 and stood at 12.7% (German average: 6.6% in 2011). The spatial footprint of those transformations is also evident in Berlin. Due to the decline of GDR industries and a restructuring of the rail traffic, large inner-urban brownfields emerged.

In all case cities despite their size, housing demands put pressure on existing green spaces. *In cities where strong environmental policy for protecting the existing green space is in place, urban planning agenda has densification as the preferred future pathway.*

In Barcelona, tensions are observed between urbanization and environmental interests due to very low availability of vacant land in the city. For example, the largest inner park of Barcelona (Montjuïc) has historically been a place where major public facilities (e.g. the Olympic sport facilities) were built because no other land was available within the municipal boundary. At present, the city council is implementing a new planning framework for the Montjuïc Park area. The new planning instrument, so-called "*Modificació del Pla General Metropolità de la Muntanya de Montjuïc (MPGM Montjuïc)*", initially included new land for public facilities (e.g. an animal shelter building) at the expense of green space, which raised opposition of some neighborhood associations.

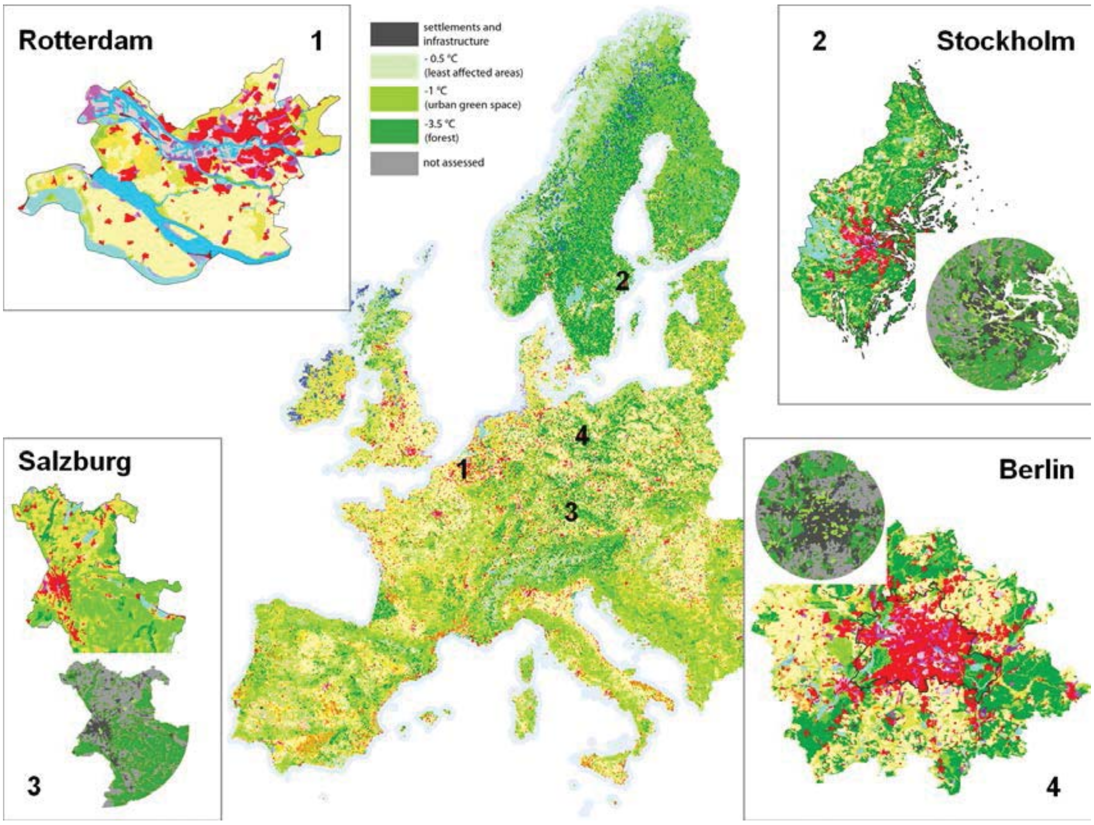


Figure 2: Maps of Europe and four case study cities showing the land use coverage. For each city, the cycle shows the cooling function of urban green infrastructure in the urban core of the case study cities Salzburg, Berlin and Stockholm.

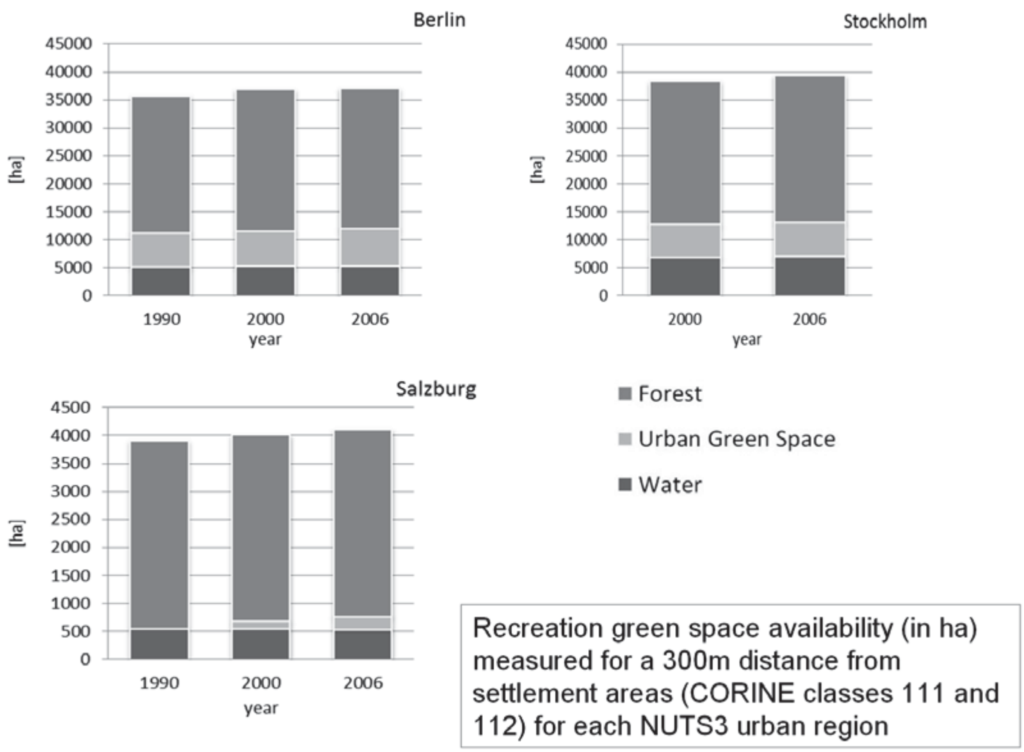


Figure 3: Recreation green space availability in three case study cities.

In Berlin re-densification in the Berlin wall area -one of the largest connecting green space throughout the city- is a long-lasting strategy in the urban agenda with recent manifestations against new housing estates in that area. The future challenge for Berlin is to safeguard and enhance existing inner-urban green space and prevent their shrinkage due to housing re-development.

Rotterdam is a compact city that sees its inner city area sparsely populated. From the 610,000 people who live in Rotterdam city, only 30,000 live in the inner city. The Dutch Statistics' Bureau states that (www.cbs.nl) "the growth rate in the three major Dutch cities, Amsterdam, Rotterdam and The Hague, was about three times as high between 1 January 2009 and 1 January 2011 as the 1.0 percent for the Netherlands as a whole." With inflow of citizens increasing per year, Rotterdam has as an urban strategy to densify its inner core and currently experiments with floating urbanization (Frantzeskaki et al, forthcoming) rather than expanding outwards. The densification strategy (Tilie et al 2012) that the municipality has in place also proposes a combined greening strategy, the symbiosis however of the two strategies is rather risky given the financial implications (e.g. too expensive to restore green in densely re-populated area) and the water management strategies that preceed the densification strategy (Delta Programme, 2012).

In the city of Salzburg, there is an increase in housing demand. Between 2009 and 2014 an increase of households by 2.09%, including an increase of single household by 1.80% and multiple-person households by 2.32% is prospected (Raos and Panisch, 2008). In face of the Green Space Declaration there are tensions between the lack of housing facilities including an increase in housing costs and the protection of urban green areas. To create more leaving space the Province of Salzburg plans, for instance, to tax vacant dwellings. It is recently put in the urban planning agenda to explore possibilities for more housing by a densification approach.

Stockholm is also experiencing an increasing pressure for new housing areas. Pressing demand for housing is observed for people with limited finances and for housing in attractive locations. Forecasts of future population growth averaging 7,000 per year to 2030 suggest that demand for housing will remain high. According to these forecasts, there will be a need for around 70,000 new homes by 2030 in Stockholm.

3.2 Socio-Ecological Dynamics

Urban green deals are plans and programs for restoring urban green spaces in cities that are either undergoing or receive increasing policy attention and relate to or build upon local sustainability agendas. Such green oriented programs can be seen as the evolution of the sustainability debates and sustainability vision and agenda processes that cities underwent over the past 5-10 years utilizing knowledge and capacity for more environmental-oriented and integrated plans for the local environment.

In Barcelona there are three urban projects that focus on green area restoration at city scale. The first concerns the Glòries square transformation. The Glòries square is one of the main road nodes of Barcelona. Due to surrounding road infrastructure, the green space located at the centre of the square has a difficult access, compromising its recreational potential. A new urban project is in progress to transform this area and to create a 13ha open green space. The second concerns the Sagrera railway station transformation. The Sagrera railway area is located in the northeastern part of the city, physically dividing the districts of Sant Martí and Sant Andreu. It is a 3.7km strip of railway facilities that will be transformed and covered to build a new major transport hub (high-speed train, regional train, metro and bus), public facilities, residential and commercial areas and various green spaces, including a linear park. The total area for urban green space is expected to be 48 hectares in total. The third project is the Collserola Gates project. In 2011, the City Council launched the Collserola Gates public tender ("Portes de Collserola"). It includes 16 projects ("gates") that have the objective to improve the connectivity (e.g. green corridors) and accessibility between the Natural Park of Collserola and the surrounding neighborhoods. The initial projects for the 16 gates have already been selected, but the implementation program is yet not defined.

Berlin experienced a rather positive transition towards more green areas in the city due to radical social changes. The slight increase of green areas can also be seen as an emerging change in Berlin. More specifically, the city center (specifically the northwest of the core city and the eastern part) locates green areas that are of high ecological quality. From 1990 to 2006 the city saw an increase of green spaces for recreation including all suitable for recreation areas (urban green space, forest and water) that is the result of two co-evolving trends: the population decline and the increase in total city area (Landorelle and Haase, 2013, p. 184; Lauf et al 2012).

In Rotterdam, the Urban Vision (2007) that continues to be the ground for all planning and development programs introduces the concept of sustainability and addresses it by suggesting connections between the green and blue infrastructure that will also ensure accessibility and attractiveness for the citizens. The sustainability objectives now dispersed in different policy and planning documents always connect green areas and the need for more green in the city to sustainability of the city. The recent urban strategy entitled "People make the city" (2012) connects densification and greening as the two interlinked development strategies to achieve urban sustainability. The green plans (Rotterdam's green vision, 2011 and the Inner-city's green plan, 2013) that stem from the urban strategy further show that the sustainability agenda has now moved towards a green oriented agenda and plan.

The re-establishment or sustaining of urban green areas is more prominent in socio-economically advanced neighborhoods, creating in this way a manifested socio-ecological divides or islands in cities.

In Barcelona, the tension between housing demand and protection of existing green spaces is on-going and remains as a challenge how the newly enforced environmental policy will hold in face of these tensions. At the same time, in the inner-city's districts where population density and compactness are high, green space is scarce and there is no strategy with supplying those areas with the 'demanded' green space.

In Rotterdam, the large-sized green spaces are maintained and protected given the scarcity of green space in the inner city. Even though accessibility to the parks is ensured and maintained, the location of the parks makes them attractive to the nearby living citizens that come from a high-income demographic. In areas of Rotterdam with high density that were build in 1970s green spaces are either absent or of low-servicing quality and as such does not contribute to the districts' liveability. To add to this, the current planning issue of how to maintain existing green space due to declining financial resources allocated to green planning and its maintenance, puts additional pressure on the green divide of the city: if the city has to choose which green space to 'save' or to 'conserve', would it be fair to keep maintaining the larger parks of the city or to find an egalitarian solution to 'save them all'?

In Stockholm, densely built areas are in need of better access to green areas as well as more green areas. In areas like Järva that were expanded during the Million Programme, an enormous home building drive in the 1960s and 1970s. Currently there is a need to upgrade the urban environment and access to surrounding green areas.

In Salzburg, the tension between the increasing housing demand and the stringent protection of existing green space is intensified by the unequal distribution of urban green areas across the city. The south of Salzburg is characterized by a high degree of urban green areas and less densely built-up areas; here housing is also more expensive and the area is characterized by its high-income demographic. The north of the city in contrast lacks green areas and its soil is highly sealed. It is thus a challenge how Salzburg –a well-equipped city in terms of urban green areas – can provide a socially fair housing and urban green spaces in areas in need so as to improve the distribution of urban green (especially in the north area of the city).

Critical role of environmental policy at local and regional level: *In cities with strong environmental policy, existing green spaces in the city were conserved despite the immense pressures for more economically beneficial ways of using the green space (e.g. housing, commercial uses).*

In Barcelona, the urbanization processes towards the natural area of Collserola created tensions between different involved stakholders. Collserola is an isolated natural area in Catalonia region, completely enclosed by urbanized land and high-capacity road infrastructures. Although Collserola is protected by a conservation plan since 1987 (Pla Especial d'Ordenació i Protecció del Medi Natural del Parc de Collserola -PEPCo), the high urbanization pressures from Barcelona and the other municipalities surrounding this area have jeopardized its ecological values. In 2010 the area was designated as a Natural Park by the regional government ("Generalitat de Catalunya"). This designation involves a clear delimitation of the Park boundaries and the implementation of new conservation and management plans (still to be approved), but the allowed land-uses within the boundaries of the Park remains a controversial issue.

The city of Barcelona did enforce a strong and ambitious environmental policy program for the city's green. Currently the most important policy document for urban green protection and restoration in Barcelona is the "Green Space and Biodiversity Plan of Barcelona" ("*Pla del Verd i de la Biodiversitat de Barcelona*"). This plan was recently (January 2013) presented by the City Council (Urban Habitat department) and is the strategic instrument defining the challenges, objectives and commitments of the City Council related to urban green space and biodiversity conservation. The Plan has a long-term implementation horizon (2020) in order to fulfill the following objectives: 1) Preserve and improve the natural heritage of the city, preventing the loss of species and habitats; 2) reach the maximum amount possible of green space and foster its connectivity; 3) Maximize the delivery of ecosystem services from urban green space and biodiversity; 4) Make progress on the value that citizens assign to green space and biodiversity; 5) make the city more resilient to emerging challenges such as climate change. The Plan includes 10 strategic guidelines with various specific actions. The assigned budget for the period 2013-2015 amounts to 62 million Euros.

The question in mind is: Does the existing policy plan in Barcelona suffice for withholding pressures and conserving the existing green space? A clear planning and management policy concerning the allowed uses in the Natural Park of Collserola is also needed to preserve urban ecosystems and city's biodiversity. Strategic planning such as the "Green Space and Biodiversity Plan of Barcelona" or "Collserola gates" seem interesting policy instruments to face these challenges, but their effective implementation is a great challenge itself.

After 1990, Berlin entered an era of joint planning (of the former West and East Berlin). The joint planning put as priority the planning of a green way system along the former Berlin wall. Being the largest European City, Berlin's districts have autonomous green space and environmental planning and management system. Despite the devolved local administration and planning at district level, Berlin lacks a city-wide tree cadaster that is a prerequisite for effective green infrastructure planning. Despite this, environmental planning and policy in Berlin adheres to National Environmental Standards and serves city's sustainability agendas. The city saw an emerging greening, where after 2005, one of the largest inner-city green spaces in Europe emerged with the close down of the airport of Berlin Tempelhof.

In Salzurg, the Green Space Declaration (Grünraumdeklaration), implemented 1985 in Salzburg and since 2008 implemented into the town charter, 3,698 ha green areas (57% of the whole urban area) are protected from further land use such as settlement or mobility infrastructure. The Declaration protected the green areas and lead to no land use change transformations. Indicatively, even though residential areas increased in Salzburg between 1990 and 2006 from 3370 ha to 3401 ha (CORINE database), and the mobility infrastructure expanded from 501 ha to 503 ha (in the course of zoning) between 1997 and 2010 (Statistical Yearbook of the City of Salzburg), the urban green areas only had a minor loss of 2 hectares the past years (between 2005 and 2009). At regional scale, since 2007 the new Regional Development Concept (REK) renews and monitors the implementation of the Regional targets set by the REK-1994, maintaining in this way policy continuity and a monitoring on actions towards sustainable urban development and landscape preservation.

In Stockholm, environmental policy was set early on to protect existing ecosystems from the rapid urbanization. In 1994 a large piece of land and water area in a big city area was set apart and protected by a special law in order to preserve its nature and culture in our time and for future generations. Nationalstadsparken (also called Ekoparken) is a unique experiment in cohabitation of city and nature. Through a decision taken by the Stockholm Municipal Council a number of nature and pen-air recreational areas in Stockholm are to be investigated for possible protection measures in the form of nature or cultural reserves (The Stockholm Comprehensive Land Use Plan 99) the list of nature or cultural reserves will be extended due to planning process on green areas in the city and ongoing work on the project of Green Walkable City Plan. In addition to this, the Environmental Code (1999) is a policy code about nature reserves protection measures with a number of objectives for biological diversity and accessibility, i.e. people's right of use and access to the areas. Stockholm's environmental policy regime is further empowered by the Stockholm Environmental Program 2012-2015, the Regional Plan of Stockholm (RUFS 2010) and the Stockholm Planning and Building Act that promotes the conservation of the green areas of Stockholm positioning them as vital parts of the innate beauty and identity of the city. For monitoring and evaluating the policy and plans, the city has in place monitoring and survey systems that collect data for regular updating and adapting city's development planning including green area development.

The regulatory services of ecosystems are recognized by planners and policy makers and as a result, greening strategies are included/exist in climate change policy agendas and environmental agendas; whereas indirect benefits of ecosystems such as the cultural services are neither directly considered in urban planning nor in environmental policy in the cities.

In Rotterdam, the majority of the policy and planning documents including strategies and visions, address the importance of green areas and well maintained waterways and canals (singels in Dutch) for creating urban climate buffers in case of extreme events. Restoring nature and using green as a rather 'affordable' technology that serves both ecological and social needs is a planning practice in Rotterdam city (Urban green vision, 2011; Inner-city green plan, 2013). In policy and in practice (cf. interviews with stakeholders) recreation, amenity and spiritual benefits from urban green and blue infrastructure are not addressed neither considered. The dominant planning paradigm insists that the urban waterways are used for goods transportation supporting the local and national economy and growth, whereas green areas are needed for climate regulation and buffering.

In Salzburg, additionally to the Regional and City policy on protection of green spaces and monitoring of actions towards creating a sustainable urban environment, the city has a integrated environmental framework in place protecting the green net Salzburg with the aim to improve climate regulation, supply of recreational areas as well as aesthetical functions and the connection of habitats. The regional development concept (REK 2007), where the green space declaration is also integrated, demands the integration of urban ecological aspects as well environmental and nature protection into the urban planning.

The rise of an ecosystem approach in planning of the cities is evinced and advocates/promotes restoration of ecosystems in cities including both green spaces as well as waterscapes in cities.

In Rotterdam, an urban deltaic city, in which the waterways are vastly used for goods transportation rather than for recreation or amenity, recently the City of Rotterdam with the guidance and cooperation of the Delta Commission (Ministry of Infrastructures and the Environment) (2012) restored the river banks of the inner-city's district Boompjes into green banks – unsealing soil that was lastly being sealed as part of the embankment and canalization of all the three rivers that cross the city. At the same time, in several districts previously pedestrianized squares are now designated to be restored into green squares with space for trees, allotments and places for people to see, enjoy and experience green.

In Stockholm, the Royal Seaport is an area that is currently under redevelopment adopting an ecosystem approach. Stretching from the area Hjorthagen, across a port area to Loudden in the south, the Royal SeaPort is being built on land that was previously used for industries, including oil refineries, and for dumping of industrial waste. The construction of 10,000 new residences and 30,000 new workspaces began in the early 2000's and will continue through 2030. The aim is not only to conserve, but to also *increase* biodiversity and to make the Royal SeaPort one of the world's first climate-positive urban areas. The over-arching goals are to keep CO2-emissions below 1,5 tons annually per person by the year 2020 and to have a climate-neutral and fossil fuel-free city area by 2030.

Urban planning and governance agencies start to consider socially organized initiatives about community gardens, community maintained parks and urban agriculture but there is still no mechanism to scale-up the lessons and successes of those initiatives to city level.

In Barcelona, the City Council via the "Pla Buits" initiative currently fosters the restoration of 20 vacant and brownfield sites. Non-profit organizations can implement interim uses of public interest in these sites, including social and environmental projects such as allotment gardens.

In Rotterdam, urban agriculture may have started as an experiment with a handful of pioneers turning vacant land into greenhouses and advocating 'eating from your city' in 2011, but now is a social trend with more than 140 initiatives in the city in 2012. The motives of the first urban agriculture initiatives include amongst others the respect of natural processes and the need to prove that food production should not be separated from the city and that it can be done following sustainable ways.

4. The on-going transitions to eco-cities

Cities are spaces where the co-evolution of change processes result in social-ecological transitions. Looking at the paths of the cities, we observe that they transformed from build spaces for people to live and work to spaces where living in the city required careful planning for accommodating not only residential and business needs but also needs for recreation and amenity. Most European cities have been through this transition from the built city to the planned city by the end of 1990s. The rise of global environmentalism and the transformations that came along with the ecological modernization of public and private systems of provisioning, affected the way cities are organized, planned and lived by. It set in motion a new transition, from the planned city to the ecosystem city or simply, to the ecocity. An eco-city – also mentioned as ecological city, green city, emerald city, biophilic city (van Bueren 2009; van Bohemen, 2012; Yang, 2013; Beatley, 2011; 2012;

Platt et al 1994; Newman and Jennings, 2008, Fitzgerald, 2010, Owen, 2009, Newman et al 2009)- is a city that has good quality green spaces that are accessible to the urban dwellers and tourists, are well maintained and well distributed across the urban area. The urban planning context of the ecocity builds on the planning regime of the planned city and has binding and implemented environmental policy that (van Bueren 2009; van Bohemen, 2012; Yang, 2013; Beatley, 2011; 2012; Platt et al 1994; Newman and Jennings, 2008, Fitzgerald, 2010, Owen, 2009, Newman et al 2009).

> "in an eco-city, (…) the environment will be properly protected and maintained while the society and economy develop smoothly, which promotes human development.. Seriously considering the relationships between humans and nature led to the final conclusion that humans must develop in harmony with nature to realize their own sustainable development." (Yang, 2013, p.5).

The meta-analysis of the five case study cities reveals that compact cities face a number of urging **challenges** that need to be carefully addressed during their social-ecological transition. Urbanization in a slow driver of change that should not however be neglected. The slow moving change processes alter demands for housing and appearance of the urban environment and are met with marginal changes of land use and mainly with renovations, restorations and refurbishing of existing areas into more efficient and sustainable configurations. At the same time, compact cities face the pressure of increasing housing demand that is or will be met with densification strategies within the existing city boundaries. Compact cities are in need for more green and for carefully planning infill strategies so as to ensure accessibility to existing green spaces. Conserving and maintaining green spaces is at the top of the priority in all case cities, but 'speaking truth to power' brings us to the following emerging challenge for having a just social-ecological transition: At present, the re-establishment or sustaining of urban green areas is more prominent in socio-economically advanced neighborhoods, creating in this way manifested socio-ecological divides or islands in cities. It is therefore important to ensure that restoration or re-establishment of urban green is distributed across the different districts / areas of the city for all urban dwellers to have good quality accessible green space that meets their needs and promotes a safe urban environment.

Building on the meta-analysis results of the five case cities, we conceptualize two types of drivers of their social-ecological transition towards eco-cities: supportive drivers that enable their transformation to eco-cities and enhance or build capacity for change and accelerating drivers that push and pull the cities to transform towards eco-cities.

Supportive drivers of a social-ecological transition in compact cities deducted from the case study cities include the following:

- ***Capitalizing on existing institutional and knowledge capacity of cities' urban planning***. Urban green deals are plans and programs for restoring urban green spaces in cities that are either undergoing or receive increasing policy attention and relate to or build upon local sustainability agendas. Such green oriented programs can be seen as the evolution of the sustainability debates and sustainability vision and agenda processes that cities underwent over the past 5-10 years utilizing knowledge and capacity for more environmental-oriented and integrated plans for the local environment.
- ***Existence and implementation of strong environmental policy at local and regional level that promotes the conservation of existing green spaces.*** In cities with strong environmental policy, existing green spaces in the city were conserved despite the immense pressures for more economically beneficial ways of using the green space (e.g. housing, commercial uses).

Accelerating drivers of a social-ecological transition in compact cities deducted from the case study cities include the following:

- ***Urban reconstruction or refurbishing projects (medium and large-scale) include green restoration plans and strategies that also consider blue infrastructure (waterscapes)***. These are seen as smart green solutions to integrate green elements in urban refurbishing addressing at the same time the need for accessible green spaces and for (more) equally distributed green spaces.
- ***Green-oriented or simply, greening strategies are included in climate change and environmental agendas, resulting in greening action that is supported, initiated and advocated from different policy centers***. Here lies a contradiction: we can argue that having green strategies scattered across different policies and plans (with no uniform or combined green oriented agenda) may result in uncoordinated action due to institutional disintegration, there is a benefit of having multiple departments allocating resources in greening strategies: different locations turn green in the city aiming at providing different benefits. From an ecosystem services perspective, a green space that has been created to serve as an inundation area (primary function) can also be used as a space for recreation (secondary or non-indented function) providing in this way multiple benefits.
- ***Socially organized initiatives about community gardens, community maintained parks and urban agriculture are the emerging green-hearted niches that take over empty or sealed areas in the city and turn them into community enjoyed and restored green.*** These emerging niches are creating green spaces of different sizes and bridge social needs with ecosystem benefits. The community gardens and urban agriculture areas are not only 'greened' areas but places for people to meet, to exchange ideas and as such, create (or restore) a sense of place.

5. Conclusion

Urban socio-ecological transitions in cities exemplify complex dynamics that require not only careful planning and policy designs but consideration of how past and current planning practices have created either path-dependencies or sufficient conditions for a positive transition. Even when significant drivers are in place, the challenges in the coupled social-ecological urban system result in a slow-moving transition. Understanding urban social-ecological dynamics urban is critical for cities to foster their adaptive capacity and accelerate urban transitions towards urban resilience and long-term sustainability.

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Changing without change?
The entangled transition of the urban water sector in Denmark

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Contents

Abstract 2
1 Introduction 2
1.1 Aims and analytical approach 4
2 Research design 5
3 The historical transformation of the Danish urban water regime 5
3.1 An hygienic and modern paradigm as the point of departure 5
3.2 The establishment of an ecological paradigm 6
3.3 The development of an integrated perspective 9
3.4 The marketization of water services 14
4 Discussion 18
5 Conclusions 20
6 References 21

Abstract

In the last decade, due to climate change impacts, increasing urban development, increased stress on natural resource and gradual aging of the technical infrastructure on place, the Danish urban water sector has realized the need to invest more generously on the optimization of technical performances and the innovation of management approaches in favor of non-structural measure and more integrated perspectives. On one hand, municipal plans have put an increasing attention on terms like urban livability, resilience and sustainability mostly resulting on an increasing focus on the need to create green and blue recreational spaces in the city-scape. On the other hand, in a context of economic downturn, national strategies aim at promoting the eco-innovation of the water sectors to support the Danish water industry competitiveness in the international market and create new jobs nationally. At the same time, a series of institutional changes were actuated: in 2007, reforming local government structures and redistributing environmental policy planning responsibilities at the local and national scale and, in 2009, formalized a first step toward the liberalization of water utilities in order to regulate water prizes by creating a benchmarking system to set precise terms for a national competition on water service efficiency. The expectations were increased capacity for municipality to regulate and water utilities to actuate the necessary investments and lower or more homogenous water taxation for users. Such cascade of changes was expected to contribute to destabilize the Danish urban water regime, preparing for the acceleration phase of a radical socio-technical transition towards more integrated approaches to urban water management. However, using the MLP as analytical lens along a 100 years timespan, the urban water regime seems to have experienced a sequence of transformation pathways characterized primarily by the reorganization of regime actors, who appear to be very fast in responding to external pressures and thus favoring only incremental niches to emerge and stabilize. But, if the same transformations are placed in a co-evolving urban context, we observed that the water regime has largely contributed to radical changes at the urban scale. By undertaking such a broader perspective, we found increasingly relevant the role of power, politics and agency in advancing or hindering urban transitions. Furthermore, we found very useful the concept of multi-regime interactions to better characterize the influence of co-evolving regimes and the consideration of geographical and spatial scales to analyze the existing tensions between national strategies and municipal plans in a complex process of urban transformation. We concluded that the transition of the urban water regime is still ongoing and it will depends on the ability of internal, external actors and intermediaries to develop a shared and more holistic understanding and definition of problems and needs to co-create a path which could contribute to “better” urban futures.

1 Introduction

In the context of climate change and economic downturn, Danish municipalities are facing important challenges in relation to urban water management. Sewer systems are under pressure as a consequence of more frequent intense rain and increasing runoff produced over the urban surfaces due to more and more impervious areas. Groundwater quality suffers from increased pollution from decades of intense farming activities and industrial development and surface water quality is endangered by more frequent overflows from combined sewers and low quality water runoff from urban impervious surfaces. Besides, political attention on surface water quality has increased with the purpose of enhancing its recreational use in order to improve citizen’s safety and quality of life and protect the natural environment at the same time. In this context, the operation and maintenance of urban water infrastructures becomes more critical, also due to the increased uncertainties related to future urban scenarios and the fact that Danish water users are traditionally not used to take responsibility on the development and maintenance of the centralized urban water infrastructure, whose development have been ensured by public subsidies and the traditional end-of-pipe philosophy to problem solving.

These challenges however, are not so different from the ones faced by the European urban water regime. Indeed, to respond to such challenges three important documents were published by the European Commission and Parliament: the Water Framework Directive in 2000, the Flood Risk Directive in 2007 and the White Paper on Climate Change Adaptation in 2009 (EC, 2000; EC, 2007; EC, 2009). All bring the resilience of technical solutions to long term changes, efficiency, cost recovery and social awareness into focus. Furthermore, “non-structural measures” (i.e. green infrastructure) and integrated approaches within a catchment based perspective are seen as a preferable approach than further developments of “physical infrastructures”.

Municipalities and utility companies, in Denmark, are now struggling to put the national translations of the European directives and recommendations into practice at the local scale while dealing with climate change adaptation and infrastructure rehabilitation. Traditionally, urban water management, in Denmark, has focused mostly on the underground infrastructure. The functioning of the urban sewer systems has always been complex but still comprehensible and usually considered more or less independent of the aboveground urban structures and transformations. Lately, Danish water engineers and urban planners have realized that to deal with the uncertainties and variability of climate change and urban development, it is necessary to combine underground and aboveground measures (Copenhagen municipality, 2011; Fryd et al., 2010; Fratini et al., 2012; Backhaus and Fryd, 2012; Zhou et al, 2013).

As a response to the above introduced international landscape pressures and inspired by emerging innovation dynamics at the national scale the new Danish Minister for the Environment, in charge from 2011, have taken the “urban water issues” on board as a central focus area in their new “Eco-innovation Program” which recommends a paradigm shift for the development of more integrated solutions in regards to urban and water planning, especially in the field of storm water management (Danish Minister of Environment, 2012).

In parallel, the Danish water regime is experiencing a series of institutional transformations, actuated by the former liberal government, in charge until 2011, in order to enhance the efficiency of local administration and decrease public expenditure: in 2007, local government structures were reformed by devolving regional responsibilities on environmental monitoring and planning to municipal and national administrations and, in 2009, a first step towards the liberalization of water services was formalized by corporatizing municipal utilities and regulating water prices via a benchmarking system setting precise terms for comparative competition on the efficiency of water utilities at the national level. The expectations were increased capacity for municipality to regulate and for water utilities to actuate the necessary investments for innovation, and lower and more homogenous water fees for users.

As a consequence of the cascade of landscape pressures and institutional reconfigurations, the Danish water sector has now started to invest more generously in the optimization of technical performances and in the innovation of management practices in the direction of more integrated approaches. In other words, the urban water regime entered the predevelopment phase of a transition in the name of more “green” and integrated approaches for the management of water in urban areas. The question which remains yet to understand is whether the present urban water regime will be able to overcome the traditional management logics developed in a century of subsequent transformations to fulfil evolving socio-political needs and expectations, and which made the Danish water industry internationally recognized as market leader in respect to waste water and water supply technologies developed across the 20th century (Arnbjerg-Nielsen and Henze, 2012; Jensen and Iversen, 2012).

1.1 Aims and analytical approach

In this paper we present an historical analysis of the co-evolution of institutional configurations, actor-networks and technical innovations of the Danish urban water management regime from the 19th century to today. The aim is to describe and compare past and present configurations of the Danish water management regime to analyses the emergence of internal and external dynamics and its interactions with the urban context to understand and characterize potentials and limitations for a radical socio-technical transition, able to facilitate the "eco-innovation" of the Danish water industry while contributing to advance urban livability at the same time.

The analysis is built upon a multilevel level perspective (MLP) in order to test the framework in describing and analyzing regime dynamics within an urban context and in presence of a cascade of changes, characterized by increasing landscape pressures, institutional re-configuration, the emergence of competing niches and the re-arrangement of actors' networks.

The relevance of the urban context in this analysis brought us to take into consideration a number of important aspects influencing transitions within cities (Raven and Verbong, 2009; Farías and Bender, 2010; Hudson and Marvin, 2010; Smith et al., 2010; Markard et al., 2012):

- the flexibility of regime boundaries in case of multi-regime interactions;
- the role of power, agency, strategic and political agendas of niche and regime actors and their networking abilities ;
- the importance of considering the influence of geographical and spatial scales (i.e. international, national, regional, municipal);
- The role of intermediaries and their mediating roles among co-evolving regimes and competing niches.

In our historical analysis we identified 4 phases in which a new paradigm get established within the urban water management regime, thus producing a re-definition of problems and socio-political needs the regime is ought to respond to and thus transform, usually as a consequence of important landscape pressures. The hygienic and modern paradigm is our starting point to analyses how the regime transformed to first respond to the establishment of an ecological paradigm, then to respond to scenario uncertainty due to climate change and the non-stopping urban transformation, asking for more integrated approaches between water, environmental management and the planning of urban spaces, and, finally, to respond to efficiency requirements as a consequence of the marketization of urban water services.

2 Research design

This study is developed on the base of 58 face-to-face semi-structured interviews and 3 workshops involving professionals from 3 Danish utilities of different typology (with regard to size, political values and degree of commitment to sustainable management and green innovation), 4 municipalities of different typology (with regard to size, wealth of their citizens, political values, degree of commitment to sustainable management and green innovation), 2 national regulators (i.e. for nature protection and financial efficiency), the associations representing municipalities and utilities, 3 private consultant companies of different typology (with regard to size and degree of commitment to sustainable management and green innovation), 3 universities and 2 semi-private research institutes. The interviewees were chosen using different approaches aiming at covering most of the professional disciplines involved in water management and urban development, as well as varying degrees of experience/seniority and association with niche or regime structures. Other data were harvested from existing documents produced by media and the institutions and organizations mentioned above, and by an ethnographic study of 3 months in one of the three utilities conducted following the actors in daily working practices (e.g. projects, meetings etc.) while working on different case studies.

The data collection started in 2008 interviewing 9 water professionals from different type of organizations (universities, private and public sectors) and was restarted in the beginning of 2011 with the ethnographic experience and the collection of a second session of interviews, 30 in total, this time with the large spectrum described above. Then the findings were summarized, refined and validated in a third session of 19 interviews and 3 workshops involving professionals directly and indirectly involved in the Danish water sector transition with the same spectrum described for the interview campaign.

3 The historical transformation of the Danish urban water regime

3.1 An hygienic and modern paradigm as the point of departure

In the middle of the 19th century concerns about hygiene standards in urban areas started to grow. Hygiene became a specific discipline in medicine and was considered the most important mean to prevent epidemics, observed more frequently in urban areas than in the countryside (Lindegaard, 2001). Inspired by studies and development of the British water management regime, and by a sudden cholera epidemic hitting Copenhagen in 1853, Denmark implemented the first urban water supply system in 1856 and an underground sewer system in 1860. However, the sewer system had the purpose to collect only stormwater and wastewater, while solid excrements were not allowed to go into the underground sewage system and were collected at the household level to sell them as fertilized to farmers. Water supply was ensured by both groundwater and surface water resources while sewage water was discharged into the nearest canals. As Lindegaard (2001) reported, engineers were not very satisfied by such a solution for the sewage system, which was defined as "incomplete", as it was forbidden to dispose solid human waste via the sewer system, and because such waste was still nigh men handled.

In 1865, "hygiene" was established as a discipline at the Danish Polytechnic Institute and, in 1868, at the Department of Medicine in the University of Copenhagen. In 1878, the two groups, established as professionals, started to cooperate intensively in connection to the institutionalization of a new society named "Association of public health in Denmark", advocating for the need of a centralized infrastructure for the management of sewage in cities (Lindegaard, 2001). A first important claim was the need of the establishment of water closets in substitution to buckets. The development of "bacteriology [as a science] gave the physicians new arguments in their fight against the bucket system, because the possible human contact with excrements was regarded as a major hygienic problem (…) [and] engineers emphasized that the sea had the capacity to purify itself naturally and that hence wastewater could be pumped into the Baltic Sea" (Lindegaard, 2001).

Most of the Danish cities were located close to the sea or by a water front, which could support water transport. Industrialization and modernization started in Denmark in the second half of the 19th century, when factories, warehouses and shipyards were located close to harbors and market centers of the modernizing cities (Jensen and Elle, 2012). In this context, water closets and sewerage facilities were regarded to as basic elements of a healthy and modern society (Lindegaard, 2001).

In 1897-1901, the first "complete" system was realized in Copenhagen by installing water closets and long collectors along the canals and the harbor. The sewage water, a combination of stormwater, grey waters and wastewater, was then pumped without purification into the sea via outlet pipes. "The 'inner' city environment was the area to be kept clean and safe, and although the specter of pollution 'outside' was in fact raised during the debate, it was seen as a problem that could be solved by technical means" (Lindegaard, 2001).

3.2 The establishment of an ecological paradigm

But the debate on water pollution was destined to grow as water resources depletion became increasingly visible in the beginning of the 20th century. This is also due to the particular topographical characteristics of the country. The average altitude in Denmark equals 30m above sea level with the highest point of 173 m located in south-eastern Jutland. The country is characterized by a large number of small rivers, low lands and marshes and 7000 km of cost line, comprising a very large number of fjords, bays and small islands. Geologically the country consists of Quaternary deposits overlying Cretaceous chalk, limestone and Tertiary sand and clay. Such topographical and geological conformations has ensured to the country widespread consolidated and unconsolidated aquifers and thus plentiful and easily accessible surface and groundwater resources but at the same time make natural water systems very vulnerable to pollution and eutrophication. Sea waters are more or less closed and only have a minor exchange with open sea, lakes are usually small and shallow and water courses are generally quite small and thus have low water flow. As a consequence, dilution of pollutants in Danish waters is very limited (Jensen and Iversen, 2012; Stockmarr and Thomasen, 2012).

In 1930, an organized protest against pollution came by a local council representative in the north of Copenhagen claiming that wastewater discharge from the city where drifted from the sea to their coastline and demanded Copenhagen to start treating their wastewater. In 1931, Copenhagen established a commission to find a solution to the problem. Mechanical treatment plants were installed at the end of the pipe systems, including a biological purification plants in the south of the city (Lindegaard, 2001). At that time, pollution was still regarded as a public health issue only. Instead, excess of nutrients until the 70s were considered beneficial for water recipients and even able to enhance fish growth. As a consequence, in the first half of the 20th century increasing industrialization of farming and increasing production and discharge of wastewater to surface and sea waters from households, industry and irrigation brought to a serious depletion of water resources (Jensen and Iversen, 2012; Arnbjerg-Nielsen and Henze, 2012; Stockmarr and Thomsen, 2012).

At that time, Denmark had, already, a rather decentralized system of public administration: 1389 municipalities and 24 counties were responsible for many public services, and local income taxes represented 30 % of total income taxation. Decentralization in Denmark was mostly the product of the influence of a powerful and libertarian farmer's cooperative movement, emerged in the 19th century, who didn't like to be regulated by "decree from Copenhagen" (Andersen, 2001). In 1968, an administrative reform merged municipalities in 277 entities and counties in 14 entities and gave them a more important role for policy integration in all sectors, including environmental regulations.

1970-1989 is for Denmark a period of economic growth and increasing public environmental concern so politicians had all the support to develop environmental policies and push for the development of new solutions for the increasingly important environmental problems (Anderson, 2001). This also helped research institutions to focus on environmental issues and on technologies for improving the existing waste water treatment facilities (Arnbjerg-Nielsen and Henze, 2012). In 1973, increasing public understanding of the reason behind environmental pollution developed into the first Environmental Protection Act published by the Danish government and culminated in the first Water Act in 1974. The aim was to reduce the release of organic matter into water courses but the focus was mostly on industrial and urban waste water pollution, and not on agriculture. Furthermore, the government chooses not to apply the Polluters-Pay principle like it was done in the same period in other European countries (i.e. France and the Netherlands). Industries, instead, were encouraged to discharge their waste water to the municipal sewage treatment plants constructed with municipal subsidies as instructed by the Environmental Protection Act. In fact, waste water fees did not represent the real cost of the service provided by the urban water departments and in some cities, like Copenhagen, user fees were not even required until 1977. According to the Minister of the Environment the use of economic instruments was not an egalitarian option: "that those who can afford it will be allowed to pollute, and those who cannot afford it will not be allowed, and we don't want to bring class policy into environmental policy" (Folketingets forhandlinger, 1973: cited in Anderson, 2001). Such political strategy meant that the public administration took all the responsibility for pollution control. As a result, public investments on both water utilities and the capacity of treatment facilities per capita in Denmark were, at that time, significantly the highest in comparison to countries like the Netherlands, France and Germany (Anderson, 2001).

Key role in the further development of environmental regulations was represented by the 14 Danish counties that were in charge of monitoring the quality of the Danish environment and of informing national regulation. In 1984, the NPo-report, quantifying different sources of pollution in regard to nitrogen, phosphorus and organic matter, was published by the National Agency of Environmental protection on the base of a monitoring campaign carried out by the counties on the status of Danish surface waters. The report was the center of a large debate, especially in regard to agricultural sources and did not bring to any important political actions. But, in 1986, a TV news report about dead Norwegian lobster in the Kattegat (the sea area between Denmark, Sweden and Norway) opened a period of political discussions. In 1987, the first Action Plan for the Aquatic Environment was approved by the Danish Parliament. The main aim of this plan was to decrease 80% of phosphorus loads and 50% of nitrogen loads into surface waters within 3-6 years (Jensen and Iversen, 2012).

In 1988, Danish companies developed and patented advanced biological treatment technologies for nitrogen and phosphorous removal and a theoretical description of biological processes in waste water treatment facilities was modeled and developed by Danish researchers (Arnbjerg-Nielsen and Henze, 2012). The result was that these technological developments were then exported worldwide and contributed to institutionalize the end-of-pipe solution philosophy in the Danish water industry sector.

However, despite considerable investments on treatment plants and the existing political pressure for more sustainable approaches in agriculture, the goals set by the 1987 Action Plan were not completely fulfilled. Reports on monitoring activities on the 1990s concluded that the measures recommended in the 1987 Action Plan were insufficient to reach the 50% reduction of nitrate leaching, especially from agriculture.

Traditionally, water supply in Denmark was based on a combination of surface and ground water resources. In 1988, the Statutory Order on Water Quality and Supervision of Water Supply Plants was approved. This introduced quality monitory standards for groundwater extractions that are still used today. Furthermore, in order to reduce the pressures on surface waters, water supply for any use was gradually transferred entirely on groundwater. The idea was that groundwater quality in deeper aquifers is generally good preserved from above ground pollution, thus drinking water could be distributed without needing complex and expensive treatments. The national policy stated clearly that drinking water should be based on pure groundwater treated simply by aeration, pH adjustments and filtration. Already at that time, approximately 800 million m^3 of water were extracted annually. The need to protect ground water resources for drinking water purposes has been a very important driver for setting regulations for environmental protection (Jensen and Iversen, 2012). However, groundwater abstraction became so intense that, in many areas in the country, it started to significantly contribute to lowering the groundwater table and thus depleting natural water systems. The problem was however never solved and persists still today. Furthermore, "in the period 1991-2005, 1306 wells were closed as water supply abstraction wells, solely due to content of pesticides or degradation products (metabolites) and approximately 100 wells are still closed every year due to pesticide content" (Stockmarr and Thomsen, 2012).

In the beginning of the 90s, as a consequence of demands for further quality improvements in the effluents from treatment processes, new technologies were developed and combined with advanced control strategies. These technologies are still market leaders. According to Arnbjerg-Nielsen and Henze (2012), such technical innovations were possible because Danish regulations "have been formulated in a non-exclusive way", meaning that they set requirements without suggesting a given technological approach.

In 1997, the second Action Plan for the Aquatic Environment (APAE II) was developed on the base of an evaluation of measures prepared by the National Environment Research Institute in collaboration with the Danish Institute of Agricultural Sciences. The APAE II focuses mostly on nitrate leaching from agriculture and had to be implemented before 2003. An evaluation in 2003 concluded that the targets were met. This evaluation was largely criticized and contradicted by environmental NGOs, claiming that it had a too narrow focus on specific indicators. A large debate on reduction targets was initiated especially regarding the change in instruments from regulatory (i.e. on the base of indicators) to economic (i.e. polluters-pay principle). In 2000, the Water Framework Directive was published by the European Union and it had to be implemented by the member states before 2015. The directive had a larger focus, requiring targets for all water bodies and stricter requirements for phosphorus and nitrogen loads from agriculture.

The Implementation of the European Water Framework Directive was the base for launching a third Action Plan for the Aquatic Environment (APAE III) in 2004. The process of developing the new plan was involving a larger group of stakeholders, including both the environmental NGOs and the agricultural associations. The APAE III for the first time made a clear connection between water pollution and agricultural practices (Frederiksen, 2011). Furthermore, the Polluters-Pay principle was included in the national regulation. In part, the implementation of WFD has contributed with a shift in management regime from end-of-pipe to catchment based focus. Still, the APAE III requirements emphasized mostly on indicators and not on management approaches. And the NGOs, this time part of the decision making process, was no more criticizing such approach while instead started to use the indicators on their own working reports (Frederiksen, 2011). Furthermore, the implementation of the APAE III has been characterized by a significant rise in the use of the indicator vocabulary in the reporting regime for both monitoring and evaluation activities. Some experts have claimed that the institutionalization of indicators for environmental requirements in Denmark has contributed to set a political agenda which was less open to new ideas and best practices (Frederiksen, 2011).

For the implementation of the APAE III the state and the counties were expected to make water plans, providing goals and action programs, for 4 water districts in which the country has been divided. The plans were supposed to be implemented through municipal action plans. However, some errors have been done in the developments of these plans and still today many elements for their implementations are still unclear (Sørensen, 2009).

Nevertheless, according to monitoring data from 2005, large results have been achieved despite the growing urban development and the increased livestock production, especially in the reduction of nitrogen, phosphorous and organic matters into the natural environment. According to Jensen and Iversen (2012), Danish strict environmental quality regulation have pushed industries, research institutions and farmers to develop new technologies and less polluting production methods thus positioning a number of Danish companies as leaders in the international market for environmental equipment and consultancy. Still most of such “eco-innovations” are developed to improve, optimize and further centralize the existing infrastructure thus enforcing the traditional urban water management logics. In fact, still today, most of the Danish water sector investments are still dedicated to increasing the sewage system capacity and to merge small and decentralized waste water treatment plants into larger ones. To achieve such a results increased capacity is developed at the newly merged plants and waste water is transported for longer distances with the use of longer below ground pipe structures and more powerful pumping systems.

3.3 The development of an integrated perspective

In the beginning of the 21st century a new paradigm has started to emerge. Living standards in Danish cities has largely increased together with local politicians’ ambitions to improve the quality of urban living, thus recalling a large amount of the suburban population back to city centers. A clear example of this picture is the transformation of the harbor of Copenhagen from and industrial to a bathing facility (Jensen and Elle, 2012). This extraordinary transformation, finalized in 2002, has contributed to highlight the importance of water to generate urban value. Despite such result has been achieved with a massive investment to increase the capacity and optimize the functionality of the centralized sewer facility, harbor bathing has been largely associated with the concept of green livable city and in the last 10 years the bathing facility in the harbor of Copenhagen have been extensively exploited in the international marketing of the city, which is now proclaimed the green capital of Europe for 2014. The concept is now being exported in a number of other harbor cities within the country.

This has contributed to institutionalize a cross-cutting association among urban development and urban water infrastructure, which has contributed to attire the attention of local politicians on the relevance of water management for improving urban quality (Jensen and Elle, 2012). Such political interest have been translated by the water engineers with a shift in focus from the improvement of technologies for waste water treatment plants to the reduction of the number of overflows from combined sewer systems. As a consequence, the reduction of the number of discharges from combined sewers overflows per year has become the central priority in the municipal strategies for sewer infrastructures planning.

In 2005, the Danish Government ratified the reform of local government structure which entered into force on the 1st of January 2007. The aim was to strengthen the role of national planning, distribute more responsibilities for policy integration to municipalities and enhance public participation (Østergård and Witt, 2007). The major results of this reform were:

- The abolishment of the 14 counties and the creation of five popularly elected regional councils with no responsibility on environmental monitoring and evaluation and no direct revenue from taxation. The main responsibility of the regions was to develop a vision on the base of the business development strategy prepared by the regional economic growth forum.
- Merging the existing 271 municipalities into 98 entities with a broader set of competences which were before of the counties. The municipal plan became the central plan defining spatial development and land use at the local scale. This should contain objective and guidelines for urban and rural development. Furthermore, municipalities were, from this point in time, in charge of performing environmental impact assessments and provide permission for local projects.
- Strengthening the role of national planning by transferring some of the monitoring and evaluating tasks of the counties to national institutions. In particular, national plans had from now on to provide guidelines and binding rules in regard to water resources, Natura 2000 and transport.
- In regard to public participation the planning act provided the minimum rules for public participation: before adopting any plan, impact assessment, directive and regulation at national, regional and municipal levels the public has a minimum of 8 weeks to submit their objections, comments, proposals or protests. The form in which interactions with the public have to be organized is up to the relative authority in charge.

Before 2007, there were three public actors involved in water policy regulation and implementation with distinct roles: (1) the National government, producing general regulation and legislation; (2) the counties (24 until 1960 and 14 until 2007 when they were abolished), monitoring, evaluating local planning and informing national regulations. Furthermore, counties were responsible for the management and protection of water resources and the aquatic environment. (3) The municipalities (1389 until 1960, 277 until 2007 and 98 from 2007 on), which were responsible for the integration of national policy but had to negotiate with the counties in regard to the implementation of environmental regulations on the base of the counties' monitoring results.

In 2007, the water supply system had a much decentralized structure in which two thirds of the water was distributed by 80 municipal utilities while the rest by around 2000 consumer-owned water works. Sewers operations were instead much less decentralized. Most of the 98 municipalities owned and managed the local sewer infrastructures. However, some of the waste water treatment plants were shared and thus co-owned among a number of municipalities especially in the region around Copenhagen. As a consequence, at the time the reform of local government structures was implemented, municipalities owned most of their water utilities.

One of the major impacts in regards to municipal water management of this reform was the decentralization of the counties' competences for protection and management of local water resources and aquatic environment. This meant, for instance, that after the reform, municipalities had to supervise the preservation of drinking water quality and give permission for water extraction and effluent discharge from sewers and treatment plants. As a consequence, in this new configuration municipalities were central actors for both the management and regulation of both water resources and water services. In addition, municipalities regulated the rights and obligations of consumers and property owners in relation to water utilities and the tariffs for water supply and sewerage services.

Water utilities were paid by users' fees, which had to cover all utility costs, including short-term savings for new investments. Profit on water services was not allowed and municipalities could not use users' fees for municipal expenses that were not necessary for the provision of water services. This meant that the economies of water utilities were already independent from tax-financed municipal budgets.

It appears that this new configuration facilitated the integration between urban planning, environmental protection and water management at the local scale. The urban planning system worked in a way that politicians were deciding over a general municipal plan for land use and then the singular technical departments were developing their own action plans to implement the technical measures aimed at facilitating the realization of the local land use plans and fulfil the national standards for environmental quality and nature protection. However, increasing integration was not observed everywhere across the countries. Indeed, the way the new urban planning system was implemented at the local scale can vary a lot from municipality to municipality, especially in regards to the power relationships established among politicians, bureaucrats and practitioners.

In the years right after the establishment of bathing facilities in the harbor of Copenhagen, the occurrence of sewage systems surcharge and urban floods have been characterized by a significant increase and recurrence in a number of densely populated areas of the country, for the most cases corresponding to city centers in the proximity of the cost and located in the downstream areas of the existing sewer system infrastructure. Despite the flat topography of the country, flood occurrence in urban areas was described as a new challenge by the urban water regime actors. Two major causes were identified: an increase in the occurrence of extreme rain events as a consequence of climate change and the escalation of new urban developments within already densely populated cityscapes.

Considering the already great amount of investments done in the 90s for increasing the capacity of the combined sewer systems built in the 50s in the most important city centers of Denmark, a new strategy had to be applied to handle the new challenge. A new concept entered the vocabulary of the existing urban water regime, partly inspired by the international research agenda: local handling of rainwater (in Danish "Lokal Afledning af Regnvand", commonly abbreviated as LAR). The major aim was to prevent rainwater to enter the sewer system using two strategies, creating space for storage within the cityscape and/or diverting it to areas where rainwater water could be stored, infiltrated into the soil or discharged into natural surface water. In 2007, the first Danish research partnership on the implementation of LAR solutions in urban areas started involving three major research institutes and three major urban areas in the country. The partnership involved a multiplicity of professional disciplines: engineering, urban planning, landscape architecture, economics, ecotoxicology and biology. In this new perspective rainwater was no more something to be drained out of the impervious urban surfaces but a resource that could be used to add value to urban living.

In the following year, a new standard, aimed at increasing the capacity of the existing sewer infrastructures, was published by the Association of Danish Engineers (IDA, 2008). A climate factor had to be added for the calculation of system capacity when planning and maintaining sewer infrastructure. On the base of this, a series of partnerships involving research institutions (mostly in the field of engineering), urban water utilities and central actors in the water industry started. The overall aim was "to close the knowledge gaps within prediction and control of current and future conditions in integrated urban wastewater systems". Expected outputs were "components of an intelligent real-time decision support system, following a drop of water from the cloud, throughout the sewer and wastewater treatment system and into the receiving waters" (DTU, 2012). The interesting aspect is that most of the people, part of the IDA commission developing new standards for the centralized sewage systems, were also the ones leading or partly involved in this purely technical innovation partnerships.

In 2010 the Danish Government published the action plan to promote eco-efficient technology describing the water problem as follow: "Clean drinking water, pollution of the aquatic environment, loss of biodiversity and natural assets, overexploitation of water resources, and adaptation of the water infrastructure to climate change constitute the most urgent environmental challenges in relation to water – both in Denmark and worldwide. Also, there is an increased interest in water as a qualitative element in the urban environment" (Danish Government, 2010). In regards to how to deal with such problems the action plan reads: "It is necessary to look at integrated system solutions; alternative systems for dealing with wastewater in large and small volumes; and alternative systems for supply water for a variety of purposes (…) rainwater is to be seen as a resource rather than a problem" (Danish Government, 2010).

As described above, two major niches had already emerged in the previous years in regard to integrated urban water management. As a consequence, the government recommendations were translated on the base of two competing ways of understanding and interpreting the urban water management challenges but both aiming at the "eco-innovation" of management practices, though with different approaches.

On one side there was a more incremental perspective to the innovation of urban water management practices, aiming at the optimization of the existing centralized infrastructure via a better technological integration of the existing water systems with above ground topography, improving the performance of the different parts of the water infrastructure (extraction, distribution, waste water and stormwater collection, transport, and treatment) and their interrelations using advanced computerized systems and improving maintenance practices. This approach aimed at integrating the urban and the technical catchment structures using complex mathematical models where large technological systems and centralized management approaches were preferred to decentralize systems and fragmented management perspectives. This niche was mostly lead by research institutions and actors, in the field of engineering and hydrology, which had still a large influence in the existing urban water management regime.

On the other side, a group of external motivated and thus more radical innovators, composed by natural scientists, urban planners, landscape architects and technical entrepreneurs, believed that eco-innovation should go beyond the traditional water supply, sewer and storm water systems. The basic principle was to disconnect rainwater from the sewage system diverting it locally for other purposes (i.e. storage, infiltration, evapotranspiration and reuse) within the urban space, without necessarily using pipes. Such approach required a more decentralized management and a higher users' involvement into urban water management practices.

The first group was the most legitimized within the Danish urban water regime but the second one gained increasing attention in connection to the growing interest of local politicians for the recreational use of blue and green spaces in urban areas. The debate among these two currents of thoughts was mostly related to the type of service they believed should be provided by water utilities and the cost and complexity of implementation for each solution. The first group had a large focus on engineer principles of environmental protection as an instrument to protect human health and ensure economic efficiency of water services. While the other focused more on the added value of water within the cityscape through e.g. the development of green corridors and water spots within the urban space, which they believed to improve urban quality and thus increase urban liveability and, as a consequence, the economic value of urban spaces.

On one side, the engineers claimed that if green infrastructures were to be retrofitted in existing urban areas functional complexity increases and, still today, there are no models able to simulate the influence of such local implementations on the water systems as a whole, without having to consider a large variety of uncertainties. They also believed that, despite local handling and re-use of rainwater might seem more attractive and sometimes cheaper solutions to municipal administrations than increasing the capacity of the underground systems, their implementation require complex decision making processes because scarcity of space plays often an important role in existing built-up regions so that on the long term urban retrofitting is likely to become a more expensive solution, from an economic cost-benefit analysis perspective, than the optimization of the centralized system performances (Zhou et al.,2012; Fratini et al.,2012)

On the other hand, the natural scientists and landscape architects claimed that adaptation to climate change requires the co-evolution of different domains within an urban context and that innovative and optimized technology on its own is not enough to achieve a proper transition to a more resilient and sustainable urban areas.

Such debate is still on-going and not solved yet, but in the last 10 years has developed in a new configuration of the urban water regime. In particular, it seems that the actors from the most radical niche has now entered the regime arena without, however, managing to reconfigure urban water management practices. In particular, a large part of the urban water regime actors has shown interest to both perspectives but appear to be trapped in the traditional regime logic represented by existing management practices and institutional configurations that have been identified as the major barriers for any eco-innovation to be realized. Instead, our observation highlighted that in the last two years the regime is going back to traditional logics where increasing the capacity of the existing centralized system seems to become both a technical and a political priority.

As an example, the latest flood disaster occurred in Copenhagen in 2011 have resulted on one of the most progressive municipality in Denmark, in regard to the implementation of eco-innovation strategies for urban water management, to choose to prioritize traditional water engineer logics in their brand new published plan for dealing with extreme rain events (Københavns Kommunes, 2012).

3.4 The marketization of water services

As part of international trends, the liberalization of the water sector has been on the national government's agenda from 2001, when the political coalition composed by the liberal and the conservative parties came into power (Sørensen, 2010).

In 2001, the Danish Academy for Technical Sciences (ATV) published a white book on the status of 5 large national infrastructures (roads, electricity supply system, harbours, railways and sewage system) in regard to renovation and maintenance. The conditions within the systems were analysed in an economic context as well as a transverse survey on the socio-economic conditions based on information from the five chosen areas. The sewage systems were found to be the most problematic of the 5 infrastructure systems analysed, needing investments in the range of 1,5-9,5 billion DKK to come back to desirable status in regard to maintenance and renovation of the existing piped system. However, the authors admitted that the presence of large uncertainties on the estimation was due to the lack of specific data on the actual status of the system in many municipalities around the country. Such analysis was based on the estimation of the age of the infrastructure considering the life-span of the implemented elements equal to a maximum of 100 years. The analysis also highlighted that investments on the systems were usually decided upon political agreements between the national association of Danish municipalities (KL) and the Ministry of Environment. For example, the available data showed that large investments on the system were nationally recommended and thus locally supported in period of economic downturn, while they were nationally discouraged and thus locally minimized in periods of economic upturns. However, it is claimed that such investments were always underestimating the need of system maintenance while prioritizing system enlargements or improvements i.e. increasing system capacity or fulfilling environmental quality requirements (Mikkelsen, 2001).

In 2002 the Danish Competition Authority examined the economic performance improvements of liberalizing the water sector and calculated a potential of 175 million Euros/year (Sørensen, 2010). To achieve such a result, they recommended incentive regulation, private accounting principles and competition.

In 2005, a commission was established by the ministry of environment to come up with ideas for the reform. They recommended price ceiling, obligatory benchmarking, private accounting principles, tax liability, corporatization, environmental management and involvement of the private sector. But this proposal found a number of oppositions. The most active and critical were the Danish Water and Waste Water Association (DANVA) and National Association of Danish municipalities (KL).

In 2005, DANVA published a comparison on competitiveness between the Danish and the British water sectors in order to respond to the publication by the Danish Competition Authority. An article written on the topic by DANVA itself, reported the following citation by Tove Tray Laursen, Chairman of DANVA*: "As far as we can see, the Danish water sector is fully competitive. We have compared it with the privatized UK water industry, which is regulated by a price cap, and we concluded that water services in Denmark are fully* *in line with the British, providing high quality service at competitive prices. Our review shows that we are at least at the same level of water quality services. We have clean drinking water that tastes good and makes consumers happy (…). In addition, we clean our wastewater far better than it is done in England, and the high removal percentages in Denmark is a key reason for the on-going improvements of water quality in our lakes and streams (…). It is extremely difficult to assess efficiency. We do not disagree on, for example the Economic Council's announcement that Danish consumers pay more for a cubic meter of water than they do in England. However, we believe that we cannot assess performances on the basis of cubic meters price as there are attached some uncertainties to the statement. Looking at the prices at the household level, and correcting it with the taxes, British consumers pay actually as much water as we do in Denmark. They have in periods actually paid approx. 6% more. In addition, the English water regulator, OFWAT, reported that the water sector in England in the next 5 years is going to face price increases of approx. 18 %. (…)We can certainly learn some of the lessons learned in England. But we must remember that we are not in the same situation as they did in 1989[when they privatized the sector]. The water industry in Denmark has always been aware of its responsibility towards consumers also in terms of efficiency. Thus DANVA started the first benchmarking studies already in 2001, and this year we supplement the previous analyses with a number of process benchmarks where the utilities have the opportunity to learn and implement the so-called best practice in their own operations. The industry, along with local politicians were able to drive supplies responsibly and efficiency within the present governance framework, and therefore the Danish consumers are pleased that the Danish water sector provides services in a high quality, at a price which is 6% lower, compared to the British privatized water industry. The reality contradicts thus the conclusions of the Competition Authority"* (DANVA, 2005).

The national association of Danish municipalities (KL) has argued that the liberalization of the water sector will lead to an increase of water prices and they characterized liberalization as a centralistic move threatening the principle of local democratic control. KL claimed that liberalization of water utilities will create important barriers to integrated water management and environmental regulations, limiting the instruments at disposal of the municipalities (Sørensen, 2010).

Nevertheless, in May 2009, the new water sector reform was passed. The main characteristics of the water sector reform were the following:

- Obligatory corporatization: meaning the transformation of the municipal water departments into public utilities, 100% owned by the municipalities but with governance structures and incentives similar to those of private companies
- The establishment of a national regulatory authority (Utility Secretariat) which is part of the national Competition Authority. The Utility Secretariat is legitimized by the level of expertise of their officers in regard to economic regulations and their institutionalized independence with the mandate of defending consumers from market and government failures.
- Comparative competition among the water utilities, which are subjected to price regulations that imitate the performance incentive of the market. The Utility Secretariat sets price ceilings based on each company's current and expected expenditures, reduced by efficiency requirements, which are calculated with the use of mandatory benchmarking exercise comparing each company towards the others.

- Incentive-based price regulations of the network industries on the base of costs and allowable profit. In the Danish reform the utilities are not allowed to make profit.
- The performance benchmarking model execute a statistical analysis based on the costs drivers connected to the operation of the technical infrastructure (i.e. pipes, pumps, treatment processes, number of costumers, density etc.) for each company. The potential efficiency of a company is then measured in comparison to the best performing company. The best performing company is calculated via a mathematical model.
- Because of their market form, water utilities are allowed to borrow moneys from credit institutions on the base of their market value. This is expected to facilitate them to invest on long term revenues projects.

The discussion regarding the benefits and the possible drawbacks of such a reform are though still going on. DANVA, in particular, have been largely critical against marketization, centralised regulation and profit-making (in case this will be allowed in the future), claiming that the sector could have been modernised without centralised regulations of prices and control on efficiency performances and have specifically tried to convince utilities to keep using the organisation's model for voluntary benchmarking, which has existed since 1999 in parallel with the mandatory benchmarking developed by the Utility Secretariat (Sørensen, 2010). One think that is important to mention, in regard to DANVA's opposition to such reform, is that this organization was traditionally established as the association representing user owned utilities, which are expected to die out by merging with the larger municipally owned utilities, because not able to deal with the efficiency requirements imposed by the new regulation.

In particular, an important result expected by the implementation of such reform is the merging of small utilities into larger entities co-owned by a number of municipalities. Larger utilities are, in facts, expected to develop increased capacity and overview to deal with the water management challenges. Nevertheless, it is not yet clear how this will affect municipal capacity to fulfil their role of regulator to ensure a certain level of service. The municipalities are to make sure that the utility companies are complying with the policy requirements (i.e. environmental regulation, water conservation and urban development standards) to be implemented at the local scale. Furthermore, municipalities set the guidelines for city development and environmental protection within the municipal plans for water supply, storm water and wastewater management to be implemented by the newly corporatized utility companies.

One of the central achievements of this reform according to the national regulator, Utility Secretariat, is the clear division between the municipalities and the utilities finances. Despite, this clear division was there even before the reform was implemented, it is claimed that municipalities were keeping using illegally utility finances to cover municipal expenses not relevant for the management of water management. It is furthermore believed that market regulation will prevent that to happen because has the capacity to increase transparency and accountability. A lot of energy is indeed dedicated within Utility Secretariat to make sure that this will not happen in the new settings. As a consequence, utility investments are legitimized on the base of their relevance for the advancements of water systems and their functionality.

An important challenge concerns the institutional capacity of the national regulator. Utility Secretariat has around 15 employees and is supposed to analyse and evaluate the data of around 100 sewerage utilities and 2500 water supply utilities while, for example the same authority in Britain (OFWAT) regulates only 10 utilities and run with an annual budget 13 times larger than the Danish regulator. Furthermore, the Utility

Secretariat is only expected to regulate water utilities for economic efficiency and there are no instructions on how to report the effects of such regulations on sustainable development or environmental quality. In particular, Utility Secretariat does not have the tools and the capacity to carry out such a task and the benchmarking system is not supposed to give any indication in regard to the quality of the service but only on technical (limited to age, structure and renovation rate) and economic performances of system operation. In addition, Utility Secretariat employees (most of whom are economists and lawyers) have a limited technical knowledge on water services and environmental quality standards while large utility companies may hire lawyers, consultants and accountants to develop facts and calculations that fit the regulator's requirements while the Utility Secretariat might not have the inside and the technical knowledge to properly evaluate utility data. This is a critical factor for ensuring accountability (Sørensen, 2010). Moreover, it is hard for the Utility Secretariat to take into account heterogeneity of conditions for the evaluation of utility performance. Many are the uncertainties that apply to the model they use for performance benchmarking.

A challenge for the municipal regulators is that utility managers have usually more inside on the way to improve service levels and environmental performances than the municipal officers, who, nonetheless, have to evaluate them. In Denmark, this seems to apply largely across the country, especially to small municipalities. Indeed, at the time of corporatization the majority of the municipal employees working in the municipal water department were transferred to the utility companies. As a consequence, the municipalities were left without capacity and knowhow to assess the management performances of the newly corporatized utility, in terms of service quality. This could also be an important barrier for facilitating the integration of water management, environmental protection and urban planning logics at the local scale.

The Utility market value is constructed over the economic value of their technical infrastructure. More value the company has, more money they can invest on the innovation and maintenance of the existing infrastructure and thus have the possibility to increase their market value. However, there are no models able to calculate the market value of a green infrastructure and such infrastructure cannot be included in the calculation of the utility value. As a consequence, the utility managers may tend to favour investments on the technical infrastructure thus preventing incentives for transitioning to more integrated and sustainable approaches to urban water management. However, in January 2013 a new national law facilitating the involvement of water utilities on urban quality improvements has passed so facilitating their collaboration on the fulfilment of municipal plans.

As a conclusion, the marketization of water utilities has demonstrated to create some difficulties to crosscutting collaboration and thus to the integrated management of urban water systems. However, these are in some cases overcome by the development of good collaborative habits. But, this collaboration is further endangered by the need of the utilities to respond to centralized efficiency requirements which often enter in conflict with the focus on service quality and municipal planning requirements. These new settings are, however, interpreted quite differently from utilities to utilities and thus bring, often to very different results.

4 Discussion

The historical analysis is built upon 3 important paradigm shifts: (1) from the prioritization of hygiene values to the development of an ecological perspective aimed at preserving and/or improving the quality of natural water resources by pure technological means; (2) from the prioritization of environmental quality standards to the development of a more inclusive perspective aimed at integrating water and environmental management practices with the planning of urban spaces in a context of climate change and economic down-turn and (3) the emergence of the economic-efficiency paradigm as a consequence of the marketization of urban water services.

Adopting the MLP as an analytical lens we can affirm that the Danish urban water regime has undergone three important paradigm shifts still managing to maintain its own basic structure. Following Geels and Shot (2007)'s pathways typologies, we could say that the regime has performed a sequence of transformative pathways characterized by a number of important incremental innovations, which have not been able to triggered important adjustments in the internal regime architecture. Indeed, regime actors have maintained their power across a century because they have been fast in predicting paradigm shifts and responding to exogenous pressures by facilitating the development of symbiotic niches able to respond to the emerging socio-political needs without losing their positions of power. An important factor is that regime actors have been able to select solutions in line to the regime structure because exogenous pressures have never forced them into radical approaches by requiring new management means. From a very simplified policy perspective, new regulations have only imposed incremental level of performance, first to fulfil environmental quality standards, then to increase the system capacity to respond to climate change and finally to improve the economic efficiency of system operation.

However, by complexifying further our perspective e.g. placing the water regime transition within the urban context we realized about aspects which might suggest the possibility of future developments which could cause an important reconfiguration of the regime itself. Within an urban context, the water management regime is co-evolving and possibly interacting with other regime in transition. In shift (1) the water regime has started to largely interact with the environmental management regime, which was also in transformation passing from the end of pipe philosophy to the natural catchment based perspective or from protecting water quality to enhancing biodiversity. At the end of such processes, the environmental management regime has split in two defined entities: the one focusing on improving environmental quality standards primarily for ensuring the health of human beings and the other focusing on the protection and enhancement of pristine nature to enhance and maintain biodiversity. The first has developed strong symbiotic interactions with the urban water management regime; while the other has grown independently within new municipal and national jurisdictions. The partial integration of water and environmental management regimes to fulfil human well-being was a consequence of important pressures by national legislation and regional regulations and brought to important technical innovations within the water regime e.g. the development of advanced waste water treatments technologies and the increased capacity of the underground infrastructures. Standards for such advancement were developed by the water regime internal actors. During shift (2) the actors of the water management regime enter in competition with the actors of the urban planning regime in regards of whose values should be prioritize when planning new urban developments. This tension contributed to the emergence of two competing niches to contribute to the water regime transformation: one, proposing urban retrofitting as a solution to this tension by integrating urban planning, water and environmental management values; the other, proposing further improvements of the technical performances of the existing underground infrastructure by adapting their functionality to the variability of the above ground structures (i.e. urban development) and processes (i.e. climate). Supported by the water regime actors and aimed at maintaining the existing regime structure, the second niches has matured and grown very fast in short time. The urban retrofitting niche, instead, haven't had the same fast developments, though increasing its visibility into the urban planning regime, which has contributed to the niche development over time (i.e. supporting experimentations and learning processes). Furthermore, as a consequence, of the increasing interest on urban retrofitting the urban planning regime has started developing more symbiotic interactions with the water regime, which has started interacting with the urban retrofitting actors, who has today, partly entered the water regime. In shift (3) the water regime is forced into an important structural reconfiguration, forcing it to clearly re-define power relations in their interactions with external actors and their role in responding to pressures and dynamics pushing for the transition of the urban area as a whole. This seems to facilitate the incremental niche to grow further and gradually enter the water regime merging with traditional practices. In particular, the water sector reform has resulted in the empowerment of those actors leading the scene on the predominant regime (technocratic perspective on service delivery) and is contributing to the gradual exclusion of the actors from the urban retrofitting niche. In this context, another co-evolving regime is entering the urban scene: the electricity regime. The water regime shift (3) was, indeed, a consequence of the spill-over of rules regulating the marketization of the two regimes. Existing landscape pressures have brought the water regime actors to prioritize energy saving over urban quality purposes, thus developing symbiotic interactions with the energy regime. An important niche is now in development as a consequence of such interaction: sludge hydrolysis. This will allow waste water treatment plants to produce energy from the further processing of the sludge produced while purifying wastewater. But for this process to become effective the sector need to further centralize the water infrastructure to develop wastewater treatment plants of large capacity across the whole country. If these dynamics will develop further they will probably bring the water regime to prioritize incremental innovations over radical ones and thus preventing the urban retrofitting niche to influence the water regime in the future.

However, if the urban retrofitting niche has not being able to enter the water regime yet is also because of the responsibility of the niche actors, who have not been strategic enough to influence the predominant regime agenda. One factor that has certainly prevented the ability of the niche actors to develop an influential strategic agenda is the heterogeneity of conditions across the country in regards to regulations and forms of interactions between the urban planning regime and the water regime. This has not allowed niche actors to develop a consistent strategy for the development of the niche across the country.

Another critical factor, for the advancement of the urban retrofitting niche, is the lack of involvement of national actors into the ongoing processes of urban transformation. In particular, this is the major reason why the development of the water sector reform has not taken into account the complexity of the context where such reform would have been implemented. This is having an important influence in the development of the urban retrofitting niche which, nonetheless, is now becoming increasingly important within the urban planning regime. Other important actors, for the advancement of the eco-innovation of the water regime in Denmark, are probably the new regions. Danish regions have, in facts, the task of developing business strategies that in some areas of the country are starting to include strategy plans to facilitate the eco-innovation of the water sector.

A very important factor for reestablishing the symbiotic interactions between the water and the planning regime would be the emergence of intermediary actors able to facilitate the process of symbiotic interactions and integrations at different geographical levels. At the national level there is the need to facilitate the interactions between Utility Secretariat and the agency for environmental protection and national land use planning. This could be played by existing association like, DANVA, KL or motivated research institutions. At the local scale the intermediary role of regions could play an important role. The problem which remains to be solved is the financial and institutional capacity to support such roles and the development of success criteria able to characterize and evaluate the approaches and the results of such intermediary actions.

To conclude, the Danish urban water sector is currently preparing for the acceleration phase of a socio-technical transition towards more integrated approaches to urban water management. However, it appears that the initial quite radical innovation journey started by the strenuous work of dedicated niche actors supported by a cascade of landscape pressures, internal water regime dynamics and, most of all, by local administrations, carrying on symbiotic transformations within other urban sectors has encountered growing resistance from actors within the water sector regime, who have invested in symbiotic but incremental innovations rather than radical ones. On one hand, the new institutional configuration brought about by the water sector reform appears to reinforce the existing regime logic rather than creating a window of opportunity to overcome path dependency. In particular, new power relations were created strengthening the influence of the water sector logics on other regimes in transition within the urban context. On the other hand, we observed that advancement of an incremental path rather than a radical one is not only the results of exogenous landscape pressures or internal regime re-configuration but rather of the fast reaction of regime actors, who managed to develop competing niches partly overcoming radical niche actors and thus transforming exogenous pressures for regime transformation into endogenous dynamics favoring incremental and symbiotic adjustments aimed at maintaining the pre-existing relations of power within the regime and the urban context. But the transition of the water sector is still ongoing and it will depends on the ability of internal, external actors and intermediaries to develop a shared understanding and definition of problems and needs to co-create a path which could contribute to “better” urban futures.

5 Conclusions

The analysis has shown that despite increasing pressures on the system to innovate and the internal institutional reform the sector has not yet experienced any fundamental changes in the water regime configuration. Actors and institutions within the regime are still trapped in a net of conflicting interests and visions. Niche actors have today become central actors in interacting urban regimes, however yet without being able to bring forward and contribute to a radical transition agenda in the water sector. This is due to the water sector regime colliding and merging with other urban regimes while local, national and regional administrations have not been able to redefine their role of intermediaries within intertwining regimes. There is a fundamental lack of strategic holistic planning at national, regional and municipal levels. Furthermore, the sector is characterized by a large degree of fragmentation due to: devolution of regional organizations (implemented in 2007), political boundaries not corresponding to physical or technical ones (i.e. catchments), local governments left alone to deal with policy integration at the local scale etc. Adding to this challenging situation, the institutional shift towards the marketization of water services was implemented without acknowledging the complexity of the system for which it was actuated and resulted in increasing fragmentation and empowerment of the actors leading the scene of the traditional water sector regime and thus in a partial lock-in of the regime transformation. It is, however, too early to say that the more radical transition of the Danish water sector is destined to fail. In fact, there are a lot of internal and external tensions and pressures that might become significant in catalyzing a radical innovation of the sector. It is evident, however, that the sector lacks intermediaries able to develop a better overview of problems and needs at the urban scale in order to inform key institutional changes and necessary policy incentives and thus translate into practice the national eco-innovation agenda.

The analysis has also highlighted the limitations of the MLP framework as a tool to properly examine and describe internal regime dynamics (e.g. institutional changes, actor agency and networking) and the need for scholars to epistemologically and analytically develop knowledge and tools that consider interactions between multiple regimes beyond innovation only targets (as in e.g. Markard and Truffer, 2008; Raven and Verbong, 2009). Furthermore, the analysis has demonstrated that the urban context brings on additional challenges for regime transformations. In an urban context, regime boundaries become more flexible and the role of power, agency, strategic and political agendas of niche and regime actors and their networking abilities become important influencing factors for the co-creation of symbiotic transition pathways facilitating urban transformation (Farías and Bender, 2010). In particular, the analysis of conflicting visions, perceptions and networks interlinking and colliding within and among multiple regimes are key to understanding urban transitions and thus we see a more flat perspective to the analyses of regime re-configurations (as e.g. in Jørgensen, 2012) suitable to provide deep insides into the complexity characterizing transition processes in urban contexts.

The Danish water sector transition has served as case study aimed at testing the MLP framework in examining the dynamics characterizing the predevelopment phase of an entangled regime transformation with urban complexity as a context. The MLP was found not suitable to sufficiently describe internal regime dynamics in the context of multiple intertwining regimes. However, the MLP still remains a very useful framework to macro-analyze socio-technological changes. Our case study shows that for transition dynamics produced by multi-regime interactions, the MLP needs to be complemented with other analytical tools, especially, in order to deepen the analysis at the micro and meso levels.

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The Power of Organizing: A New Approach to Studying Socio-Technical Transitions

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1. Introduction

Over the last couple of years research on governance has made much progress (cp. for German research efforts Benz et al. 2007; Benz/Dose 2010). We are now better able to understand how markets are working the functioning of industrial sectors and technological developments. In all these areas coordination problems have to be solved in order to allow for a smooth operation (Hall/Soskice 2001, Beckert 2007). Coordination problems are "solved" by a varying mix of private and public actors in a more or less organized manner. Governance in this context can be defined as all forms and mechanisms used for the coordination of actors, whose actions are interdependent, i.e. they can support each other in achieving specific aims or prevent them from happening (Benz et al. 2007: 9). The reflections on the importance of governance structures are theoretically informed by institutionalist thinking (Werle 2012) and analyze predominantly specific regulatory structures (Mayntz 2004). Research has been concentrated on the more static-structural aspects of governance. Most of the relevant governance literature is focusing on the internal operation of governance structures and presupposes that they are working in a more or less self-sufficient manner.

At least as important, however, is the challenge to analyze the *change* of existing governance structures. It has been sufficiently discussed that structures, institutions as well as organizations have a specific inertia (Scott 2001). Path dependence - among other factors - plays a significant role in making more radical change difficult (see Fuchs 2012; Fuchs/Shapira 2005). Verbong/Loorbach (2012) have recently established that especially in the field of energy infrastructures "transition" to a new state is hard to come by. This might be the effect of the inertia inherent in established governance structures. If we assume that to fight climate change significant changes in the way our established system of electricity generation works, have to be made, it is paramount to ask, whether the existing governance structures are fit for that task or whether we need to look for new forms or structures of governance to ensure a transition towards a more sustainable infrastructure. Studies employing an institutionalist framework or are being informed by one or the other strand of evolution theory have repeatedly and successfully attempted to show that changes especially of a fundamental nature will be the result of "external" demands (Meyer/Rowan 1977) or major crisis and shocks emanating from the environment (Gould 2002). Fundamental changes are not driven forward by the incumbent actors in a specific field, sector, organization or policy domain, but by challenger groups. The transformation of a field is linked to the successful realization of radical innovations as opposed to incremental innovations. Incremental innovations improve on existing ways, activities, conceptions, and purposes of doing things, while radical innovations change the ways things are done. Under this definition, the key to classifying something as a radical innovation is the degree to which it reverberates out to alter the interacting system of which it is a part (cp. Padgett/MacLean 2006). The development of the energy sector in the past had been determined by a small group of industrial actors along with political and regulatory decision makers (Viktor 2002). In many countries decisions on the use of specific technologies (e.g. nuclear energy, renewable energies) have not been the result of the activities of profit maximizing economic actors. The essential incentives for changes in the energy sector have come from the so called oil-price shocks in the mid ninety-seventies of the last century, the Chernobyl accident and the resulting critical attitude towards nuclear energy in many countries, the liberalization of markets driven forward by the European Commission and finally the Fukushima catastrophe.

Such external events can - under specific conditions, which need further analytical specification and empirical research -, lead to changes in governance structures. The standard operating procedure surely is to have the incumbent actors deal with external challenges in the established way of doing things (structures and actors). We assume that changes in the governance structure are not an immediate reaction to external shocks, but rather these external shocks have to be interpreted, mediated by new, skilled actors and seen as a chance to see things differently and organize and build coalitions around these new ideas of how things could be done differently. In order to be successful, a change in the relevant power constellations which supports the governance structure is required. Processes of change deal with the question, who gets what under what conditions, i.e. they transform power structures, create new practices and new rules.

An explanatory perspective, which would allow us to better understand such processes, is the evolving Theory of Strategic Action Fields by Neil Fligstein and Doug McAdam (Fligstein/McAdam 2011, 2012), which we use in the following as a basis for our discussion of changing and/or stable governance structures in the energy sector and its consequences for the successful implementation of new technologies.

2. Analytical Framework

The energy system is a prime example of a large technical system (Mayntz/Hughes 1988, Mayntz 2009) characterized by a substantial degree of institutional inertia. To adapt to new demands from public authorities and consumers, the energy sector needs to show a significant degree of flexibility. The more intensive the organizational needs, and the more complex and empowered a socio-technical system's structures are, the more demanding and protracted a substantial transformation will be. This is especially true for the tightly knit networks and the capital-intensive organization that exist in the energy supply system.

The case studies that will be introduced in the following, analyze and highlight different aspects of the process of sectoral change. Before discussing the four cases it is important to clarify the overall analytical framework that tie them together.

2.1 State of the Art

For our analytical purposes we could have used more classical institutionalist approaches (sectoral innovation systems, technological innovation systems) or perspectives that stress a potential system transformation to a more sustainable state of whatever is at stake (transition approaches). However, we have opted for an approach – the theory of strategic action fields as developed by Fligstein and McAdam (2012) – that seems best able to cope with the following very special circumstances:

(a) Our research object concerns not "one" technology and its development, and technological challenges do not constitute the main driving force for the changes in the energy sector;

(b) We are primarily interested in the dynamics of a process and not so much in analyzing more or less stable institutions;

(c) We see the development of the system as open ended and characterized by competing aims and visions.

Research so far has developed different analytical approaches to study sectoral transformation. Some of these will be briefly discussed here to help better understand the theoretical option we have chosen.

One important line of reasoning can be associated with the so called "transition"-literature. It claims to have an analytical apparatus that would help us both understand as well support infrastructure transitions towards a more sustainable state. Research done in this tradition meanwhile shows an amazing breadth (see Truffer 2012). Nevertheless, it faces some shortcomings. It has an implicit normative character, arguing that transition processes will and have to go in a direction towards more sustainability. We actually see transition processes as being open ended. The outcomes of these processes are the product of a struggle between actors who define sustainability in different ways, and favor different strategies and methods. A cornerstone of the transition approach is its emphasis on niches. Niches are important since they contain the seeds for transition processes. Niches therefore have to be protected, and new technologies have to be experimented within these niches until they are ready to help transform the system. We share the view that transformation or radical change from within a system or sector is unlikely. We doubt, however, whether the niche concept provides the best analytical concept for understanding transition processes. Niches by themselves do not necessarily transform a sector. Niches are to be found everywhere. There are niche markets which thrive on the simple fact that they concentrate on niches, e.g. by offering very high quality or specialized products or services which are relevant only for a tiny minority. However, radical change in sectors such as telecommunications, was not driven forward by niche actors but by political decisions and powerful actors from outside the field.

The niche argument ultimately tends to underrate actors' aspirations and strategies which may or may not aim at sectoral transformation.

Another line of reasoning is represented by the Technological Innovation System approach. Again, this approach has produced an impressive number of valuable studies over recent years and we can benefit from their results (Coenen/Lopez 2010). Pioneering work on TIS was carried out by Bo Carlsson and Rikard Stankiewicz (1991). They define it as: "network(s) of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology. Technological systems are defined in terms of knowledge or competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks." (Carlsson/Stankiewicz 1991: 111). Given that technology is the common denominator in TIS, a framework can be used that is geared to studying how the configuration of actors, networks, and institutions changes over time as the technology develops (Carlsson 1997). Recently, the emphasis on a dynamic analysis of TIS has received considerable impetus by explicitly focusing on the functions, activities, or processes taking place within the system of innovation (Hekkert et al. 2007, Bergek et al., 2008). It remains somewhat ambiguous, however, how exactly the boundaries of a technological domain are set in relation to its geographical and sectoral embeddedness. Markard/Truffer(2008) remain critical of the inconsistent way that empirical studies of TI-systems have delineated the system, using it either in a rather descriptive way as a synonym for sector or just as a catchword. From a sociological point of view the use of the systems metaphor and its more or less arbitrary listing of functions and treatment of institutions has been criticized.

Recent theorizing in the social sciences in general has stressed the importance of the meso-level and especially of meso-level social orders where actors (who can be individual or collective) interact with knowledge of one another under a set of common understandings about the purposes of (in our case) a specific sector, a field, the relationships there (including who has power and why), and the sectors’ rules (cp. Martin 2011). Observing actions in meso-level social orders has already been implied in the various versions of institutionalist thinking. Meso-level orders have been variously called sectors, organizational fields, games, fields or networks. Most of this theorizing, however, is very static. It is difficult to use the insights produced by these studies to investigate change. Concepts like, for example, "institutional" or "organizational logic" are well suited for analyzing periods of stability, but not for the study of processes of (potential) transformation.

Interdisciplinary innovation research, finally, has also stressed the importance of the meso-level for understanding respective processes. For example, a whole series of research has been done under the label of "Sectoral Systems of Innovation" (Malerba 2004). This research, however, also suffers from an under-conceptualization of the processes of change and transformation. In the institutional tradition, processes of transformation are described as "periods of mismatch" (Dosi et al. 1988: 11) or as "periods of considerable confusion" (Henderson/Clark 1990:12). Thus a more thoroughgoing analysis is necessary that highlights the interplay between incumbent, stabilizing, and changing forces.

2.2 The Theory of Strategic Action Fields

In our view, the theory of strategic action fields provides an analytical framework that enables the analysis of dynamic developments, is not normatively based, and is also not technology centered.

2.2.1 Who and What Can be Drivers of Change?

We conjecture that a strategic action field is dominated by a set of incumbent actors who share a common belief about what the field is all about, how specific positions are attributed to actors, what the aims of the field are, and the legitimate ways to pursue these aims. From a plentiful supply of empirical evidence and theoretical considerations, we can safely assume that incumbent actors will try to oppose demands for change that will destabilize their position in the field and dominant ways of doing things. Change will therefore be driven forward mostly by challenger actors, less powerful actors within the strategic action field under analysis, or from outside actors "invading" the field.

2.2.2 What Are the Mechanisms Producing Change?

External developments that have relevance to internal field processes can include the following: political decisions such as the *Energiewende* or the liberalization of energy markets; changes in macro-cultural discourse such as the growing awareness of the dangers of climate change; or widespread external opposition against specific technological options such as nuclear energy. For significant change to take place, these external developments have to pose significant threats, or provide opportunities for the realization of collective interests. Those delivering the threats or opportunities must have command over sufficient significant resources in order to be able to generate and sustain action. Significant changes to a field will also require the use of innovative and new – possibly previously prohibited – forms of collective action. The role of individual or corporate skilled actors is paramount. They need not only to fight for a new interpretation of what the field is all about, but they will also have to forge new coalitions and compromises reaching beyond the initial set of challenger actors.

2.2.3 What Can Be the Eventual Outcomes?

Analyses of processes of sectoral transition have shown that such processes as well as their outcomes are difficult to predict and might take different forms such as: (a) a re-imposition of the old regime with some adjustments; (b) the break down into unorganized social space; (c) the partitioning into several spaces (e.g. renewable vs. traditional energy generation); (d) the development of a wholly new regime (Cp. Mahoney/Thelen 2010, Fligstein/McAdam 2011). We reserve the term "transformation" for the last option.

3. New Technologies, Governance and the Energy Sector

The energy system globally faces a variety of challenges which require adaptation. Large energy infrastructures are the precondition for economic development. But the dominant ways of generating electricity extracting them from fossil fuels (coal, oil, gas) have been made responsible for the human induced part of climate change. The technological part of a solution to the challenges of climate change is twofold: a) Alternative ways of generating energy can be developed and implemented; b) the use of fossil fuels can be made more climate friendly.

These are then the two options: either develop and use new technologies for energy generation or make existing procedures and facilities work in a more socially desirable way. In the following I will analyze the so called Carbon Dioxide Capture and Storage (CCS)- technology as an example for the latter option, which is aiming at making conventional power plants work more climate friendly, issue less emissions. The CCS technology is considered by the International Energy Agency as the only viable and available technological option if you want to continue to use and build conventional power plants and reduce CO2 emissions at the same time. A more decisive challenge for the existing governance structure is coming in the past and future from the area of renewable energies. The traditional way of generating electricity has as its backbone a centralized structure with big electricity generating units, which are run by a small group of potent firms. Renewable energies on the other hand are not only vying for attention with the claim to develop a new, climate friendly, secure way of electricity generation, but also favor a decentralized design, demanding and offering new roles for entrepreneurs as well as consumers. A totally new form of governance seems possible.[1]

4. The Development of CCS in Germany and Norway

[1] The present paper draws on the results of four research projects dealing with the development and prospects of CCS and PV. The projects used document analysis, expert interviews and discussions, scenario analysis and agent based modeling as methods. The projects were supported by the Volkswagen Foundation, the German Federal Ministry for Environmental Affairs, the University of Stuttgart and the Helmholtz Association,

Using the example of CCS we will analyze, how the governance of technology-oriented incremental innovations in the energy sector looks like and how different actor constellations and structures in a similar sector can lead to a big difference in outcome and performance: a stalling development in Germany on the one hand and a successful implementation based on a broad social consensus in Norway.

4.1 CCS in Norway

For generating electricity Norway uses nearly exclusively and traditionally water power. The significant domestic oil and gas reserves are nearly exclusively used for export purposes. Owing to this, the discussion on CCS in Norway was advanced by actors, which did not have a significant role in the domestic electricity providing system as such. Leading actors for development of the technology and a suitable governance structure had been the oil company STATOIL and research institutes like SINTEF and the Technical University of Trondheim (NTNU). Already in the 1980s the idea of capturing and storing CO2 had been fancied. At the same time Norway's minister president Gro Harlem Brundtland chaired the *World Commission on Environment and Development* of the United Nations. Under her chairmanship a comprehensive report on sustainable development was published. In 1991 Brundtland introduced for Norway a CO2 tax for fossil fuels and fossil fuel using sectors. This tax helped increase efforts over the 1990s, to push forward plans for the capturing and injection of CO2 into oil and gas fields. Initially this happened as pure research efforts but gradually also in the form of projects testing whether the procedure was commercially viable. The interest of the oil- and gas industry is derived from two activities linked with the CCS technology: the so called EOR (Enhanced Oil Recovery) and the EGR (Enhanced Gas Recovery). By both methods CO2 is injected into off shore oil and gas fields in order to improve the efficiency of exploitation. This framing of the technology quickly brought other actors onto the playing field and the developing actor network. Norway's biggest industrial plant constructing company Kvaerner and international oil companies contributed to the research efforts. The driving force in Norway thus has been the oil- and gas industry which started R&D activities as well as partnerships with scientific institutes. Its prime interest was the injection and storage of CO2 in the nearly empty oil and gas fields.

Starting in 1996 Statoil began with the first commercial use in the gas field Sleipner West in the North Sea. From 1997 onward research activities for CCS also did get public support money from the KLIMATEK program sponsored by the Norwegian government. After Kvaerner had been successful with starting its first pilot installation of a CO2 capturer, Norway's second biggest technology company, Aker, also invested in R&D for CO2 capturing.

Only later on became CCS of great significance and interest to the Norwegian system of electricity generation. Growing electricity demand could not any longer be matched by domestic water power alone. Environmental concerns were discouraging the building of new water dams. At this moment the Norwegian energy provider Naturkraft did get a license to construct two new gas fired power plants. A lively debate on the construction of these new power plants emitting CO_2 ensued. Influential environmental organizations were favoring the implementation of the CCS technology for the new power plants. It seemed to be the only option, if attempts to decrease energy consumption were not successful and if on the other hand the government wanted to stick to the political aim (in the meantime also laid down in the Kyoto Protocol) to reduce CO_2 emissions.

Since the private R&D activities, the Norwegian policies as well as the geological storage potentials made ever bigger research efforts possible, which were now also supported by the European Union (in spite of the fact that Norway is not a member of the EU), CCS gained solid support among the Norwegian public and most of the active NGOs. The initial debate on whether to build new gas fired power plants turned into a debate about the pro and cons of the CCS-technology (cp. van Alphen et al. 2009: 49), which was easily won by the supporters of CCS coming from different camps. Since 2011 the official Norwegian policy is guided by the idea that no new concessions for gas fired power plants will be granted if the CCS technology is not used.

Concluding it can be said that CCS in Norway was driven forward by a growing and broad coalition of actors coming from politics, industry and civil society. The development of the technology did not lead to a disruptive change, but was inclusive, oriented towards existing actor coalitions and broadening them in a largely consensual manner. In the Norwegian CCS case the field structures were not fundamentally transformed, but due to external pressures new types of actors were coopted into the field. The government succeeded in framing the problem as one of caring for sustainable development. It built a broad coalition of industrial and civil society actors supporting the CCS technology. Overall the field showed a high degree of adaptive capacity and was able to push technology development forward.

4.2 CCS in Germany

An analysis of the governance of innovation for CCS in Germany gives a strikingly different impression. First of all coal (absent in Norway) still plays an important role for electricity generation in Germany. 24% of the energy generated in Germany has brown coal as its source; an additional 18% are derived from hard coal (UBA 2011). The brown coal used is nearly exclusively coming from domestic sources and is at the same time the only competitive domestic fossil material used for energy generation. After a period of stagnation, coal fired power plants are again dominating the German market, i.e. most running or planned construction projects are coal fired power plants (cp. Pahle 2010). In its role as buyer of power plant technologies the German energy providers have a substantial interest in technological innovation that would allow them to continue running the coal fired plants and build new ones. This refers to a further improvement of technology already in use to increase efficiency, but also to an interest in CCS, which would lower CO_2 emissions significantly. Since Germany has committed itself to an ambitious climate policy (40 %- CO_2 reduction target planned by the Federal Government), the energy providers and operators of the coal fired power plants feel a considerable pressure to reduce emissions.

The major importance of coal for the German electricity provision system is also highlighted by the fact that Germany is considered to be a worldwide leader in the development of technologies relevant for the running of coal fired power plants (Weimer- Jehle/Wassermann/Fuchs 2010). Innovation activities in the area of coal fired power plants and CCS in Germany are executed by a limited number of predominantly big actors. These are multinational companies like Siemens, Alstom and Hitachi Power Europe, which as dominant constructors of power plants build technically highly developed components like turbines, boilers and generators, producing them in a more or less identical manner for the German as well as the world market. Innovations are driven forward in clusters of research networks in which extra-university research institutions (e.g. Research Center Jülich), big university institutes, the R&D departments of the producer companies and the R&D departments of the customers, usually the four big energy providers RWE, E.ON, Vattenfall and EnBW are represented (cp. Rogge/Hoffmann 2009: 7) – sometimes all of them at the same time. Driving actors in the development of CCS and the spread of its idea in Germany therefore are the firms constructing power plants, the domestic brown coal industry, the big energy providers, which operate the majority of the German coal fired power plants and which are worried about the emission trade schemes and increased costs.

Given the importance of the constructing firms from an industrial policy point of view, early R&D activities were supported by the Federal Government. The leading actor in this respect was and still is the Ministry of Economic Affairs (BMWi). Within the so called COORETEC- Initiative for the promotion of research and development of future oriented power plants with fossil fuels, research projects and pilot installations for the capturing of CO_2 were supported. At the site *Schwarze Pumpe* in Brandenburg, a big and traditional brown coal extracting area, the worldwide first trial installation for a CO_2 poor brown coal fired power plant based on the Oxyfuel-procedure was built. The pilot installation started work in 2008 and was run by the energy provider Vattenfall. The aim was to test and further develop the technology in order to make it commercially viable. In a parallel effort Vattenfall also developed a 300 MW-demonstration project, which was supposed to start operation in the years to come. It was planned to be again situated in Brandenburg, this time at Jänschwalde. In contrast to the Norwegian situation the driving forces for the development of CCS clearly came from the incumbent actors of the field. Insofar innovation activities followed an established incremental course typical for this type of field, based on the interests of the incumbent actors and their networks. It soon became clear, however, that the second step in the CCS-development process (looking for suitable sites to store the captured CO_2) run into difficulties. For this part no established mechanisms were available and the approval of actors became necessary, which hitherto did not play any role in the calculations of the coalition driving forward CCS. The commercial exploitation of CCS at the end had to cope with severe acceptance problems which threatened the success of the whole innovation process. Massive resistance against the exploration of possible storage sites became organized. Various citizen initiatives came into existence, which gradually gained the support of environmental organizations, but also from other associations, like the „Farmers' Association" and the Association of Water Power Companies (Schulz/Scheer/Wassermann 2010). After massive protests, the regional (state) governments became reluctant in their support for the Federal Government's plans to push CCS. Especially the resistance of the state government of Schleswig Holstein made it impossible to pass a federal law on CCS. As a consequence the energy provider RWE stopped its plans for building a demonstration power plant using the CCS technology in Hürth (Northrhine Westphalia). Even before this decision RWE had failed in its attempt to gain EU support for the project. The EU named as a justification for its decision the resistance against the search for storage sites in Germany. The only existing legal approval for the exploration of potential commercial CO_2 sites, two sites in the state of Brandenburg, were based on state regulations, given the absence of federal rules. The permission was granted, however, with the idea in mind that a new federal law would soon be passed, which would then grant legitimacy to the state's actions. Since the federal law did not materialize, the state government announced that the exploration permit can only be considered as temporarily valid. As of now all attempts for a new federal regulation have failed and as such the technology implementation process looks doomed. Similar to the situation in Norway the technology development process was advanced by established industrial actors, based on political decisions favoring the technology. Just like in Norway climate policy consideration in line with the established networks consisting of the Ministry of Economic Affairs and the incumbent actors in the field, worked out the respective plans. Unlike in Norway, however, CCS did not succeed in building a solid support coalition reaching beyond the established field actors. Decision making took place in closed circles until the necessity arose to go public in the search for storage sites. The CCS support coalition basically consists of the incumbent actors facing a growing and influential counter movement consisting of citizen initiatives, NGOs, who succeeded in broadening their coalition (in contrast to the incumbents). Whether Germany will be able to implement CCS in the years to come, in spite of the fact that technology and knowledge is available as well as political priorities, seems very doubtful at the moment. The field CCS in Germany at the moment can thus be best described as an unorganized social space. Actors are unsure what to do and how to proceed. Most likely only a decision by the European Commission will restart the process.

5. The Governance of Photovoltaics in Germany and Japan

Contrary to the more incremental innovations in the area of climate friendly technologies for coal and gas fired power plants, the development and diffusion of renewable energies includes a variety of new actors – especially in Germany. These new actors encompass new producers, electricity traders as well as owners of decentralized electricity generating units. Discussions about global warming and general environmental concerns have led to political attempts to create and manage a new energy market and the newly developing energy mix. New political instruments were developed and at least in Germany new actor constellations can be observed, which in consequence have led to the development of a specialized governance structure for renewable energies.

5.1 Photovoltaics (PV) Development in Japan

The beginnings of PV research in Japan date back to the 1960s. The company Sharp was engaged in the development of solar cells for space research. As a result of the oil crisis in the 1970s, which Japan due to its near complete dependence on the import of fossil struck especially hard, the Japanese government started in 1973 a first political program, the so called "Sunshine Program", with the aim to explore possibilities to reduce the dependence on energy imports. A small part of the overall program, ca. 6 Mio $, was devoted to PV research for terrestrial applications.

At the center of the Japanese innovation system is a small number of big, vertically integrated as well as diversified companies, which are specializing in incremental innovations in products and production processes. The second most important actor for the governance of innovation is the government. It is much more directly involved and makes much more direct attempts to coordinate innovation processes than its counterpart in Germany for example: „Japan and Germany clearly display different social systems of innovation, and this is why these countries showed contrasting patterns of evolution during the last quarter of the twentieth century" (Boyer 2003: 148). Vogel (2006) furthermore points to the important differences between German and Japanese innovation policies: „The German government merely facilitates private-sector coordination, whereas the Japanese government organizes and guides the private sector more directly. The German government has codified its economic model into law, whereas the Japanese model relies more on informal norms and standard practices." (Vogel 2006: 308).

The Japanese government has interfered actively with a variety of measures and strategies in the development of the energy sector. This can be shown for the energy sector as a whole but also very clearly for the case of PV. Following the 2nd oil price shock of 1979, the government in 1980 created the *New Energy Development Organization* (NEDO) with the aim to reduce Japan's dependence on foreign oil. NEDO is an adjunct to the Ministry for International Trade and Industry (MITI), which is also responsible for energy questions. In 1988 NEDO was renamed to

„*New Energy and Industrial Technology Development Organization*" and thus stressed even more its coordinating role for the industry (cp. Ristau 1998: 81). Members of NEDO were recruited from the state apparatus but also from industry. As such the energy provider *Tokyo Electric Power Company* e.g. played an important role in the formulation of the energy policies and strategies of the organization.

Over the 1980s NEDO fulfilled two important functions for the development of PV: on the one hand it sponsored research projects for the improvement of the efficiency of solar cells. On the other hand NEDO became also the biggest buyer of commercially produced solar cells. In the 1980s there was neither a domestic nor an export market for PV- applications. The state sponsored demand was a decisive benefit for the Japanese industry, which was aiming at developing a world leader position in the development of this technology. With the eventual development of a world market for PV, Japan was able to satisfy the growing demand and expand its market share on the world market substantially. „In 1983 23% of the worldwide sales of modules originated in Japan. Two years later the European Solar Association calculated that the contribution had grown to 45%"(Ristau 1998: 81; own translation G.F.). The strength of the Japanese innovation system which can also be demonstrated for the case of PV is not to be seen only in the type of cooperative policy support but also in the political instruments used for technology diffusion (e.g. the financing of demonstration projects, incentive programs). In order to give the industry incentives to expand production capacities, MITI initiated in 1994 the so called 70.000 roofs program („*Monitoring Program for Residential PV Systems*"; Shum/Watanabe 2009: 3536). It was implemented by the *New Energy Foundation* (NEF). Within the scope of this program the government financed 50% of the installation costs for PV-modules of private households. Under specific conditions firms could also participate in the program. The financing of the overall program was done with the help of a surcharge on regular electricity tariffs. The energy providers furthermore were obliged to buy PV-electricity at market prices. In 2003 the program was further developed. But now the government took over only 15% of the installation costs. Before that in 1997 a new energy law was passed („*Law on Special Measures to Promote Use of New Energies*"). It consisted of a broad mix of subsidies and other policy measures to support the spread of PV and other renewable energies. A clear target for the expansion of PV was also stated. PV was supposed to grow from 500 MW to 5000 MW until the year 2010 („*Long-term Energy Supply/Demand Outlook*"). Other laws naming targets for the spread of PV ensued as well as a number of projects which were especially supposed to boost public demand for PV (e.g. installations on public buildings). The Ministry of Education e.g. passed an ECO-School project, the Ministry for Infrastructure Development a *Green Government Office Project* and between 1992 and 1998 a *Field Test Project on Photovoltaic Power Generation for Public Facilities* was done, which later on was merged into the *Field Test Project on Photovoltaic Power Generation for Industrial and Other Applications* (Anderson et al. 2006: 26). The public expenditure for the support of PV in the 1990s was significantly higher than in all other comparable nations. The public budget in

1997 for the support of PV amounted to 150 mio Euro. In Germany at this time no public money of any significance was spent for this purpose. Less than half of the Japanese support money went into R&D support; the bigger part was used for the stimulation of demand (Ristau 1998: 92). Since 1997 the support was extended with a further „*Program for the Development of the Infrastructure for the Introduction of Residential PV Systems*“. In the following years (from 1997 to 2001) the support grew from 11,11 Mrd. Yen to 23,5 Mrd. Yen (Shum/Watanabe 2009: 3536).

The technology developed and implemented in Japan resembled a standardized mass product without any significant adaptations to the needs of specific customer groups (Shum/Watanabe 2009: 3540). The dominant Japanese type of an integrated innovation process can thus be observed for the case of PV. This included the integration of the „last mile“, the installation or de-installation of PV-modules by artisans and architects. Shum and Watanabe refer in their analysis of the Japanese governance of PV-innovations to the image of a „closed development“(Shum/Watanabe 2009: 3540). The development of PV in Japan therefore resembled other comparable innovation processes in Japan. In the center of attention is the cooperation between the incumbent actors from government and industry. They are aiming at developing products which can also be exported and sold on the world market and thus help the domestic industry. For the realization of the aim of PV development established channels and methods of cooperation were used, in order to push the innovation forward in an incremental and piece-meal fashion. In spite of the first mover position of Japan both with respect to technology and commercial development, a position which Japan could hold on for quite some time, the amount of installations realized in Japan was not overwhelming. In this regard it is important to understand that Japan did not succeed in creating a real domestic market for PV installations. PV installations are primarily to be found on public buildings. The incumbent actors, the same companies that were doing e.g. nuclear power development were also doing PV, had their prime orientation towards exporting products, but did not favor a significant change of the domestic technology mix. The composition of the coalition deciding on the further development of the energy sector remained stable, new challenger groups (e.g. from civil society) did not play a significant role and as such more wide ranging changes were not envisioned. In Japan the type of coordination used for PV therefore resembled the established patterns in the electricity generating field. The development was towards a technological add-on option, but was not intended or used to break up the existing way of coordinating strategies. The actors concentrated on strategies that would not endanger their existing position and business models which were dominantly oriented towards developing and using nuclear energy.

5.2 PV Development in Germany

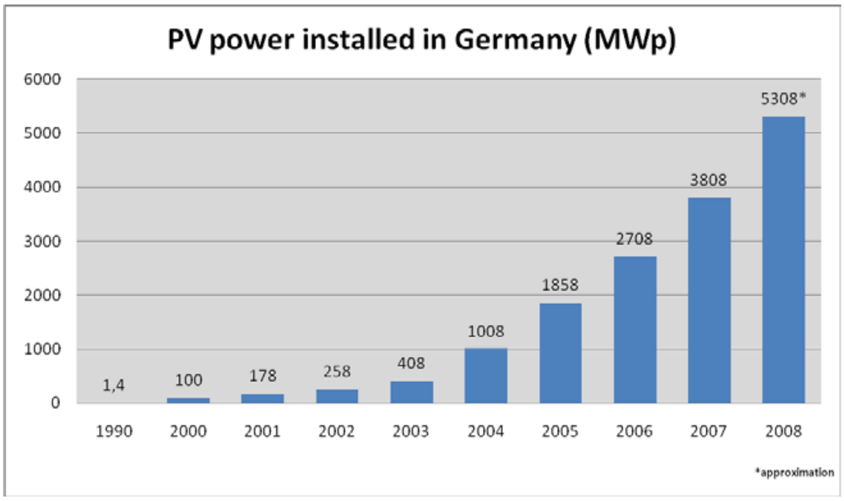
The German PV development in contrast to the Japanese case is characterized by severe conflicts, radical innovations and marked breaks and changes in governance. In the already discussed examples we detected more or less continuous efforts to sustain R&D and support efforts based on coordinated and cooperative efforts of the main actors from government, science and industry. The German PV picture looks different. For a long time government support was rather reluctant and difficult to predict and liable to sudden changes and shifting priorities. In contrast to Norway and Japan as well as the CCS development in Germany, the momentum for the development of PV was kept alive by so called non-conventional actors. In this case the social movement character of governance change becomes clearly visible.

Initiated by the oil crisis, Germany started first programs related to PV and other new energy options in the 1970s. At this point in time the responsibility for promoting PV was with the Ministry of Research and Technology. With the ensuing decline of oil prices and following a change in the composition of the federal government – it was now led by the conservative party -, the programs to support PV were severely curtailed. The first programs for PV nevertheless had certain successes. The industrial partners (AEG-Telefunken, Siemens-Solar) having received most of the public money, succeeded in establishing a competitive expertise and technological prowess. The German PV-research could be established and gained an internationally leading position along with Japan and the US. Unlike in Japan, however, the little public money available was widely dispersed, experiments with various technologies and procedures were supported and universities as well as applied research centers, like the Fraunhofer Institute for Solar Energy Systems (ISE) (founded in Freiburg in 1982) were participating. Research projects became financed which were not evaluated from the side of the funding institution with respect to what technological option would be the most desirable one and what would be the best option for industry and/or society. In the end, however, the efforts were seriously hampered by the fact that technologies were developed up to a pre-market stage, but given the lagging or non-existent domestic demand combined with little political interest in supporting an uptake of the technology, this led to a stalemate and no significant role for the technology in electricity generation could be established. On the contrary: the further development of the technology was opposed by the incumbent actors of the energy system equipped with good networks and contacts to political and administrative decision makers. Clear policy guidelines were furthermore difficult to establish due to conflicting positions of the Ministry for Economic Affairs, who claimed responsibility for market oriented support schemes and which until the present day sees PV very critically and the Ministry for Research and Technology which had and has a more favorable view of PV (Ristau 1998: 44ff.).

The general support for technology development therefore was rather weak and divided. The support coalition for PV mainly consisted of concerned scientists who wanted to develop an alternative way of generating electricity. Their engagement very often grew out of an opposition to nuclear energy. The Association for Solar Energy (DGS) (founded in 1975) tried to pool their interests and became more important due to external events. The Chernobyl accident in 1986 made nuclear energy very unpopular and initiated a new search for alternative energy resources and a discussion about the future outlook of the energy system as a whole was restarted. Within two years the opposition against nuclear energy among the population at large rose from 50 to 70% (Jahn 1992). The scientists favoring PV were trying to influence the public discussion and put PV on the agenda as a possible new option, as an important element of a transformed energy system. PV was labeled as a clean, environment friendly source of energy. This made it possible to merge the interests of different social groups: the anti-nuclear power movement and environmental groups could quickly agree on such an option, which made it also possible for them not only to be against something, but to be in favor of a true alternative option. In comparison to other countries the social movements and the general opposition to nuclear energy after the Chernobyl accident was more wide spread and also found a political support in the party "The Greens/Die Grünen". Given this changing environment the federal government felt obliged to offer some carrots in the form of a first, small market oriented program for supporting PV. In 1991 the 1000-roofs program started. It was financed by a state controlled bank (Kreditanstalt für Wiederaufbau) and offered loans for private households, which were interested in participating in a big test of grid connected PV-installations. NGOs like the aforementioned DGS, the Association for the Promotion of Solar Energy and Eurosolar used this situation to influence the political agenda. They developed various models for the financial support of PV and the technical options for connecting decentralized generated solar energy to the general grid. Besides these national developments other institutional innovations on the global and the European level were important, which also had an effect on the German PV scene. On the European level the deregulation of the energy system was driven forward by the European Commission and the global discussion about climate change, which led to the Kyoto protocol (1997), altered the framework within which PV could be developed. The groups favoring solar energy became more firmly organized and built up new political coalitions especially on the local and regional level. On the federal level, however, things looked different. After the heavily over-subscribed 1000 roofs program was terminated, the demand for PV installations plummeted again and decreasing energy prices seemed to make PV an economically unviable solution. The market nearly disappeared and the relevant industry threatened to or actually left Germany to move to locations that would provide a more stable regulatory framework. It became clear that without a long term oriented regulatory framework and support scheme no significant demand for PV could develop in Germany. This was again a situation in which the role of non-conventional actors proved decisive. Greenpeace paid the Ludwig-Bölkow-Foundation for doing a study on the feasibility of constructing a production facility for PV modules in Germany. The study came to the conclusion that it would in fact be economically viable to produce and use PV modules in Germany (cp. Welt online 1995). Considering economies of scale and an automatisation of production processes the price for PV-installations could be reduced by 40%. Even a small production unit with the capacity to produce only 2000 PV units would be able to work profitable. These results were used by Greenpeace to look for people interested in helping finance such a plant. Within a short period of time 4000 people showed their interest. Greenpeace then put ads in leading newspapers to look for entrepreneurs to realize their plans and suitable persons actually showed up. The major importance of Greenpeace's activities was in sensitizing the potential demand for PV and showing ways for a viable implementation of a PV production strategy. It had become clear that PV installations could be produced more cost efficiently than previously thought and the discussion thus also gained an industrial policy component (cp. Fuchs/Wassermann 2012).

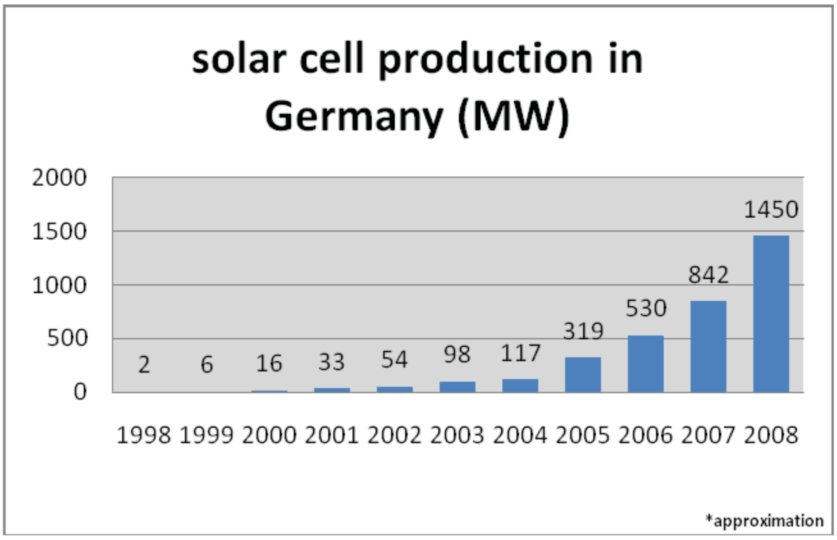
Once it had become clear that PV modules could be produced more cost effective than initially thought, especially medium sized companies began to become interested in PV – companies like RAP Microsystems in Wernigerode or the Solar Factory in Freiburg (Ristau 1998: 57). The new small and medium-sized PV companies did concentrate from the beginning on grid connected installations. They began to produce modules, mounting frames for roofs and inverters. In this way the activities instigated by the various social movements mentioned above, led to the development of a new innovation path and strengthened the specific characteristics of PV development in Germany (Jacobsson/Lauber 2006: 266). Many of the new PV start-ups had their origins in PV-research institutes. The close networking between science, environmental groups and small, initially environmentally and energy politically motivated entrepreneurs was especially valid in the case of PV.

Fig 1: PV power installed in Germany (MWp)



Source: Bundesverband Solarwirtschaft e.V. (BSW-Solar 2009)

Fig 2: Solar cell production in Germany (Mw)



Source: Bundesverband Solarwirtschaft e.V. (BSW-Solar 2009)

In 1998 the development became a new push. Another change in the composition of the Federal Government brought a red-green coalition into power. The window of opportunity now was wide open. The expanding PV support coalition saw its chance. It did not need any longer do lobbying work from the outside. Members of the PV coalition now could effectively influence policies from the inside. Its aim was an institutionalization of the support for renewable energies. The red-green coalition in fact initiated two new policy instruments for the support of PV. Firstly a successor to the terminated 1000 roof program was started, now called 100,000 roofs program, demonstrating the new emphasis and importance of promoting PV. The program was passed in 1999 and it was again administered by the bank KfW. It offered cheap loans covering a period of ten years of which two years were totally free from interest payments. For a long time the PV industry had waited for such a signal. In 2000, secondly, a new electricity feed-in law was passed (Renewable Energies Law). It set the conditions under which generated electricity could be fed into the general electricity grid and also regulated the issue of financial compensation. The Federal Government was trying to establish a broad support for the new law, but nevertheless some of the energy providers and their trade associations went to the courts and tried unsuccessfully to block the law. When in 2003 the 100.000 roof program ran out, a new amendment to the Renewable Energies Law increased the compensation for individuals generating electricity from PV modules, making PV even more interesting from a commercial point of view. When in 2005 a new shift in the composition of the Federal Government took place (now a coalition led by the conservative party with the social democratic party as a junior partner), no fundamental changes were put in place. Originally opposed to PV promotion schemes, the conservatives meanwhile looked more favorable on PV. This was essentially due to the influence of regional politicians from the

Eastern parts of Germany, where most of the new PV companies had set up business and were also attracting foreign direct investment.

	Incumbent Energy Governance	*Renewable Energy (Photovoltaics) Governance*
Aim	**Incremental innovation, continuous improvements**	**Radical innovation, new „architectures“**
Actors	**Government, incumbent energy providers, incumbent manufacturing firms (MNC), established mainly university based research**	**Government, mainly newly established medium sized companies, regional and local energy providers, strong position of extra-university research, interested individuals and environmental associations**
Networks	**Strategic networks, functionally specialized and complementary institutional institutions, clientilism**	**Heterogeneous interactive networks, experimental regimes of institutional learning, extended bargaining systems and new coalitions, heterogeneous expert groups, communities of practice**
Policies	**Regulation, subsidies for research of established actors and pilot installations, financing of public deliberation activities**	**Energy Feed In law, indirect subsidies financed by consumers, cheap credits for buying installations people, small amount of research subsidies**
Level of regulation	**Central (national) level**	**Increasing importance of decentralized levels (local, regional)**
Technological characteristics	**Centralized large technical systems with long planning horizons**	**Small to medium sized, decentralized units, flexibly and easy to install, short planning periods**
Role of „customers“ in the process of	**Primarily intermediate actors (energy providers), consumers have little impact**	**Private consumers, consumer can become producer, intermediate actors (machine tool industry, artisans etc.)**

Table one: Changes in the Governance of Electricity Generation in Germany (Differentiation)

Another political change in 2010 (now a conservative-liberal coalition took office) has made the further development of PV look unpredictable. Various regulatory changes were implemented and opinions - especially voiced again from the Ministry of Economics, the four energy providers and network operators - gained importance, claiming that PV is not a suitable option for the

Table two: Installed PV capacity in Germany and Japan (inGW)

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	
Germany	3	5	6	8	11	18	23	32	76	186	296	439	1074	1980	2931	
Japan	19	24,3	31,2	43,4	59,6	91,3	133,4	208,6	330,2	452,8	636,8	859,6	1132	1421,9	1708,5	1

German electricity generating system. Prior to the Fukushima catastrophe the operating times for nuclear power plants were prolonged and contracts made by the previous governments were cancelled – damaging the prospects of PV. After Fukushima an end to nuclear energy was proclaimed, but up until now the conditions for the promotion of PV have not become stable and calculable again. In 2011 7,5 GW PV-capacity were installed in Germany, which shows the popularity of solar energy in spite of decreasing financial returns for the investors. The Federal Government wants to reduce this build up to 1 GW per year in the future.

6. Conclusion: Governance of Innovations in the Energy Sector

In this contribution we have traced the development of two technological innovations in three countries. The emphasis on the one hand was on analyzing how technological developments are embedded in specific national and sectoral contexts for which we used the concept of governance. On the other hand we have put the emphasis on a process perspective. The process perspective is informed by the theory of strategic action fields (Neil Fligstein/Doglas McAdam). We started with the assumption that a change in governance structures has to find its expression in a change within the dominant actor constellation. Changes in actor constellations are the product of a period of contention. Actors from neighboring fields or the state attempt to change the existing field consensus and thus the position of the incumbent actors. Incumbent actors (like the four big energy providers in the German PV case) will try to defend their position and damage the position of the challengers. The outcome of such a process cannot be easily predicted. It depends on the ability of the actors to frame the situation in a light that is beneficial to their strategy, to organize around this frame and develop (innovative) instruments to push forward their aims even against resistance. For the case of Germany, we could show that the development of PV was dependent on the establishment of a new support coalition, which against the opposition of incumbent actors and interests, created a new form of governance for the promotion of renewable energies. The support coalition gradually broadened, and consists meanwhile of a broad, sometimes with respect to interests, diffuse group of actors, but which occasionally still succeed in formulating common goals. We can observe the development of a governance structure from bottom up.

The CCS technology in Germany on the other hand was supposed to be executed “from above” with the help of the established actors and networks consisting of energy providers, research institutes, hardware producers and political actors. They tried to push through a technological option against growing public opposition. The eventual failure to commercialize CCS is signified by the successful attempts of the opponents of CCS to organize and a lacking capacity of the established actors to co-opt them (like in Norway). The result is unorganized social space. In Norway the CCS development was driven forward by a broad coalition of actors which initially came primarily from outside the electricity generating sector. Successful co-optation strategies brought together a coalition of actors from neighboring fields, the general public and the incumbent actors.

	Field Change	***Field Stability***
Technology Adaptation	Norway/CCS	Germany/CCS
Technology Exploration	Germany/PV	Japan/PV

Table three: Technology and Field Development

PV development in Japan on the one hand was successful acknowledging that the main aims for spreading PV within Japan were realized. The aims were to promote the use of PV without any fundamental changes to the governance structure and the position of the incumbent actors. Of prime interest was to develop a new technology for export, which for reasons of establishing a point of reference, was also to be used in Japan. The effect, however, has been a constant, but comparatively slow development of domestic PV. PV plays a negligible role for electricity generation in Japan and no stable new market was built up. Prior to the Fukushima accident the contribution of renewables to the overall energy mix in Japan had actually decreased.

Country	Role of State Actors
Japan	Coordinating, guiding
Norway	Regulatory activism
Germany (PV)	Enabling
Germany (CCS)	Coordinating, guiding

Table four: The Role of State Actors

Within the scope of this paper the case studies could only be presented in a highly stylized way. They hopefully served the purpose, nevertheless, to show the validity of a new analytical approach to study energy transitions. With respect to discussion on the environmental state, one needs to reflect to what extent the case studies can be considered to be "typical". Within the scope of this paper we cannot go into detail about the justification, why we have actually picked these four cases and not other ones (cp. Gerring 2007). The case of electricity generation poses a special challenge for the ecological state. On the one hand functioning energy infrastructures are of vital importance for modern societies and energy prices (resp. subsides) are a sensitive topic both for consumers and industry. The dominant ways of electricity generation based on fossil fuels have suffered a significant loss of legitimacy as a consequence of discussions on global warming and the general environmental impacts of the burning of fossil fuels. Coal has been named as the ultimate culprit. There is no doubt that burning coal is bad for the health of the individual and has an important part in the CO2 emissions worldwide. Nevertheless the burning of coal is more popular than ever. Close to every other week a new coal fired power plant gets into operation in China. Even supposedly environment-friendly Germany has increased the burning of coal, since it is cheaper than gas in the search for compensating if for the loss of electricity generated by nuclear power plants.

Thus: even if environmental problems continue to be in the focus of national and international policy making, this development is far from being even handed, evenly spread over the various nations or is characterized by a steady increase in environmental awareness. Rather we experience leaps and bounds. As Vogel has recently analyzed the forerunner status in environmental affairs once had been the United States, meanwhile it is lagging far behind actions started by the European Union. States have built up considerable administrative, institutional and legislative capacity and devote substantial proportions of public spending towards environmental protection and restoration. But not only has the extent to which this is done differed widely between nations and even sectors. Even more so the strategies and intentions of the main players diverge. Some are treating environmental problems as an addition to the already existing list of problems to be tackled in the one or other established manner by the conventional actors. Others are considering environmental problems as a trigger to enact bigger changes in the set-up of the political apparatus and political process.

In our cases the strategies adopted by state actors (cp. Table four) differs. It can be based on the consideration that newly developing challenges and problems should be solved in the established manner: PV in Japan, CCS in Germany. Our argument is that opting for the established standard operating procedures will not produce a transformation of the field- Standard operating procedures, however, can differ nationally as well as sectorally. The same holds true for activities that aim at a transformation of the field. We tried to establish the point that in order to achieve such a result, new actors and coalitions that have so far not been active in the field need to be mobilized. Insofar the ability of challenger actors to mobilize and build coalitions for the realization of environmental states is paramount.

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Tomorrow, the world? Assessing prospects for global expansion of China's wind turbine industry using TIS functions

Submission number 132

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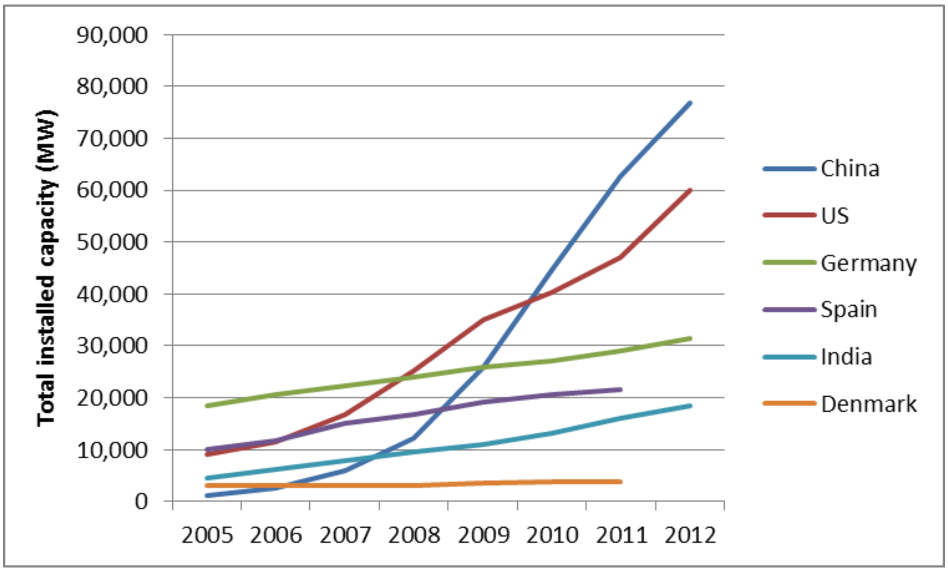
1. Introduction

Patterns of global economic development are undergoing change. By 2025, six major emerging economies (Brazil, China, India, Indonesia, the Republic of Korea, and the Russian Federation) will collectively account for more than half of all global growth (World Bank, 2011). Economic growth is understood to be strongly dependent on technological prowess (Abramovitz, 1986; Freeman and Soete, 1997; Kim, 1997; Nelson and Rosenberg, 1993). As such, the inquiry into the (changing) role of emerging economies in global innovative activity is increasingly attracting scholarly attention (De Fuentes and Chaminade, 2012; Fu et al., 2011; Lundvall et al., 2009). There are signals that emerging economies are increasingly involved in the global development of clean-tech, and especially renewable energy technologies (Berkhout et al., 2010; Binz et al., 2012; Levi et al., 2010; Pew Environment Group, 2012; Truffer, 2012).

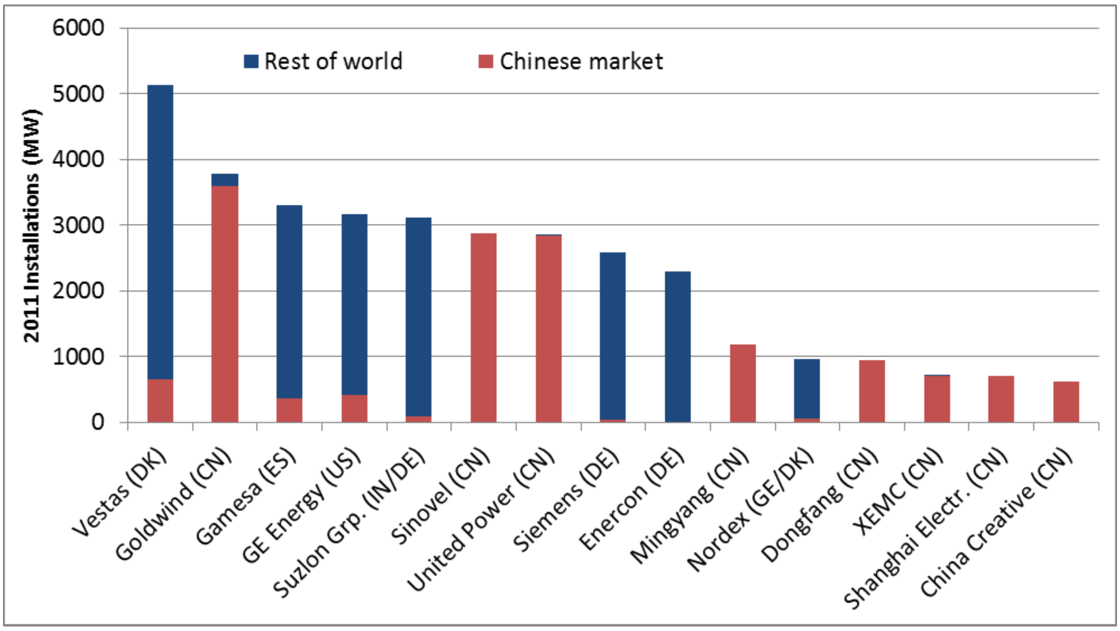
China's wind power sector is a case in point. Chinese wind power installations have outpaced those of any other country (Figure 1). Annual additions have been close to 20 GW, or half of the global total, in recent years, making China the biggest domestic market for wind power equipment. The Chinese turbine manufacturing industry has also blossomed. In 2005, there were three active Chinese turbine manufacturers, which supplied just 1.3 per cent of that years' global installations. Currently, there are around 80 Chinese turbine manufacturers, eight of which made in into the global top 15 in 2011 (Figure 2, CWEA, 2012d; GWEC, 2012a). These two developments are strongly related, as Chinese manufacturers have come to control more than 90 per cent of the large domestic market, whereas exports remain very limited (Figure 2; Table 4).

Figure 1. **Wind power capacity: global leaders**



Source: (GWEC, 2012c)

Figure 2. **Wind turbine manufacturers: global leaders by 2011 market share**



Notes: Collectively, the top 15 manufacturers controlled 84.5 per cent of the 2011 global market. Sources: (CWEA, 2012d; IHS-EER, 2012).

The domestic market can be instrumental in developing global technological leadership and a springboard for developing export markets. It can provide a requisite breeding ground for developing domestic industries and offer an environment to test and develop new technologies and products (Beise, 2005; Fagerberg, 1995; Porter, 1990). Competition for market share pressures firms to invest in innovations in product quality, which consecutively improves prospects for global expansion (ibid). The relative size of the domestic market matters, because of the perceived profitability of investments in R&D (Beise, 2005). Empirically, the export success of wind turbine manufacturers from different countries has been found to positively correlate with domestic market sizes (Beise and Rennings, 2005; Lewis and Wiser, 2007).

A relatively large domestic market is, however, not a sufficient precondition for global technological leadership and export success. These benefits will likely only materialize when (1) the domestic market is a sufficiently competitive environment, e.g., with sufficiently demanding customers in terms of product quality from their suppliers (Fagerberg, 1995; Porter, 1990), and (2) when product qualities demanded in the domestic market are similar to those demanded in the global market (Beise, 2005).

It should be noted that the literature quoted in the previous paragraphs mostly dealt with early developmental phases of globally novel technologies in advanced economies. The challenge in developing export markets differs for advanced and emerging economies, as advanced economies, by definition, were the earliest adopters of wind power technologies, circa during the 1970s. When firms from these countries started to look to export markets, wind turbines offered by competitors from other countries had undergone comparably long development and were therefore of comparable technological maturity. By comparison, the earliest of the Chinese turbine manufacturers entered the industry around the year 2000; many others followed as recently as 2005 or later. These firms have to make up a significant head-start in technological development by those competitors from advanced countries.

Because of this, much of China's policies for the wind power sector has long focused on processes of technology transfer, learning, and the localization of manufacturing in China, in other words, on processes of technological catch-up (for an overview of China's policies in early phases of the sector's develoment see e.g., Gosens and Lu, forthcoming; Lema and Ruby, 2007; Lewis and Wiser, 2007; Ru et al., 2012). More recent Chinese policies have set bolder targets, including more independent innovation, turbine quality levels comparable with the global forefront, and expansion into global markets (Table 1).

The question that this chapter seeks to answer is in how far Chinese wind turbine manufacturing, which has by now grown into a veritable industry, currently compares to the global forefront in terms of technological leadership and competitiveness. We furthermore seek to assess if current domestic policies and market conditions provide an environment for further technological progress, and by extension, affect prospects for global market expansion.

Table 1. Recent Chinese policy objectives for the wind industry

'12th Five Year Plan for renewable energy' (NEA, 2012)
• By 2015: 100 GW of wind power, of which 5GW offshore, and 190 mln kWh production. • By 2020: 200 GW with 30 GW of offshore and 390 mln kWh production • Focus on wind power bases, seven parks with 10 GW+ capacity and offshore parks • Improve innovative strength and international competition of domestic industry • Improve the servicing industry, wind power standards and wind power use efficiency • Encourage more distributed wind power utilization so that grid is not unnecessarily stressed
'Opinions on deepening technological system reform and accelerating the construction of a national innovation system' (2012-2020) (State Council of P.R. China, 2012)
• Focus on seven 'strategic emerging industries', including wind power • Improve 'independent innovative capabilities'; master key technology with control over key IPR • Formation of a number of industry giants with international influence and a batch of creative SME • Integration of domestic education and science complex with the industrial chain • Expand domestic and foreign markets
'12th Five year plan: special plan for the development of wind power science and technology' (2012-2015) (MOST, 2012a)
• Shift from quantity to quality; reach international levels in turbine performance and reliability • Master the design, production, and operation of 3-5 MW direct drive turbines, and 7 MW turbines and components • Master the development, design and batch production of very large (10MW) offshore turbines

2. Analytical framework: Technological Innovation Systems

The interconnectedness of technology, markets and policy (the latter being especially important for clean-tech; (Bergek et al., 2008a)) is well recognized in the analytical framework of Technological Innovation Systems (TIS). These systems are defined as ‘networks of actors interacting [..] under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology’ (Carlsson and Stankiewicz, 1991: p94). We may analyse TIS using a list of seven ‘system functions’; key activities required to spur innovation (Table 2).

Innovation system actors can be categorized according to their role in the innovation system. Typically, these are grouped into e.g. university and research institutes, industry, consumers, government agencies etc. The actors that will compete in export markets are manufacturers of exportable products. We will zoom in on individual manufacturers of wind turbines, and analyse how they contribute to innovation system formation, and vice versa, how the opportunity set offered by the surrounding innovation system, i.e. policy support measures and prevailing market conditions, affects operations of different manufacturers.

Table 2. Functions of an Technological Innovation System

System function	Refers to
1 **Knowledge development**	• Patenting and scientific publishing • R&D phase funding and activity
2 **Knowledge diffusion**	• Knowledge exchange in networks • Trade in and co-development of IPR
3 **Guidance of the search**	• Steering development towards specific technological alternatives • Regulatory pressure (e.g. quota for renewable energy) • Articulation of interest by leading consumers
4 **Entrepreneurial activities**	• New entrants in market • Diversification of activities of incumbents • Amount and variety in experiments with the technology
5 **Market formation**	• Size and types of markets formed • Drivers of market formation (e.g. support scheme)
6 **Resource mobilization**	• Capital • Human resources • Complementary resources
7 **Creation of legitimacy**	• Stakeholder attitudes and recognition of (societal) benefits of the technology • Rise and growth of interest groups and lobbying • Political debate in parliament and media

Source: based on (Bergek et al., 2008b; Hekkert et al., 2007)

3. Snapshot of the industry

An overview of the wind turbine industries' global leaders and Chinese manufacturers is presented in tables 3 and 4. We divide Chinese manufacturers into four tiers, based on cumulative capacity installed by the end of 2011.

Table 3. Snapshot of the wind turbine industry: details of global leaders (included in top 15)

Name	Installations (MW)				Est.	Note
	Global, cum.	China, cum.	China, 2011	Exports 2011		
Vestas	49,332	3,565	662	97.5 %	1979	Danish. Global market leader since the
Gamesa	24,143	2,966	362	87.0 %	1994	Spanish. Started operations on the basis of a design license from Vestas.
GE	?	1,455	408	36.7 %	1980	American. Predecessor Zond est. 1980. GE now active in China as a JV with Harbin Power Eq.
Suzlon Grp.	20,000	1.101	96	63.1 %	1995	Indian Suzlon acquired German RE-Power, which was active in China as JV RE-Power North
Siemens	13,700	86	48	97.7 %	1980	Germany's Siemens wind division can be traced back to Danish company Bonus, est. 1980
Enercon	28,000	0	0	48.1 %	1983	German. Not active in China. Not active in the US after patent litigation with GE
Nordex	7,543	573	50	92.0 %	1985	Danish. Active in China as the JV Nordex-Yinchuan

Table 4. Snapshot of the wind turbine industry: details of Chinese manufacturers

National Champions: more than 5 GW of installations					
Name	**Installations (MW)**			Est.	Note
	China, cum.	China 2011	Exports 2011		
Sinovel	12,877	2,939	none	2005	SOE, pure wind power manufacturer. Subsidiary of Dalian Heavy Industry
Goldwind	12,680	3,600	5.0 %	1998	SOE, pure wind power manufacturer. Goldwind's predecessor Xinjiang Wind Energy Co. was established in 1986. XWEC had experience mostly with small scale, off-grid turbines.
Dongfang	6,816	946	none	2004	SOE, power generation equipment and heavy industry group
United Power	5,252	2,847	0.3 %	2007	SOE, pure wind power manufacturer. Subsidiary of Guodian, one of China's largest utilities
First Tier Manufacturers: 1 to 3 GW of installations					
Mingyang	3,123	1,178	none	2006	Privately owned, power generation equipment group
XEMC	1,801	713	0.7 %	2006	SOE, power generation equipment group
Shanghai Electric	1,782	708	none	2006	SOE, power generation equipment group
China Creative	1,349	626	none	2006	Privately owned, pure wind power manufacturer. Spin-off from Shenyang Univ. of Technology
Windey	1,098	375	none	2001	SOE, pure wind power manufacturer. Spin-off from Zhejiang Inst. of Electro-mechanics.
Second Tier Manufacturers: 300 MW to 1 GW of installations					
CSR Zhuzhou	1,037	451	none	2008	SOE, large industrial conglomerate, core product is locomotives
CSIC Haizhuang	877	396	1.0 %	2006	SOE, large industrial conglomerate, main activity is shipbuilding
Envision	747	348	none	2008	Privately owned, pure wind power manufacturer
Yinxing	473	221	none	2007	SOE, provincial utility and power generation equipment manufacturer
HEwind	405	151	1.0 %	2005	SOE, large industrial conglomerate, core product is electrical apparatus
Energine	380	49	none	2005	SOE, subsidiary of China Aerospace S&T Corporation (CASC), which previously was in a JV with Spanish Acciona. Energine produces wind turbines and rare earth applications
Sany	323	180	6.3 %	2008	SOE, manufacturer of heavy machinery
Third Tier Manufacturers: less than 300 MW					
Annual additions for these firms have been 50 MW or less. This is considered very small in China, as wind farms are mostly developed in 50 MW sections, with a single equipment supplier. This group contains around 50 firms, about half of them state owned and about half private firms. The bulk of these was established 2008 or later.					
• Jingcheng (prev. Beizhong) ((200 MW)	• XJ Group (192 MW)	• Tianwei (189 MW)	• New United (167 MW)	• Changxing (150 MW)	• Sharpower (80 MW)
• Huide (84 MW)	• Ruihao (45 MW)	• Jiuhe (Geoho) (20 WM)	• Guoce (GC) (14)	• Hanwei (14 MW)	• 43 others (122 MW)

Note: CSR Zhuzhou should go into tier 1 based on total installations but is more comparable to tier 2 manufacturers in terms of company age, number of customers and geographical spread over different provinces in China. Sources: company annual reports and websites for the global leaders; (CWEA, 2012a; 2012d; CWEEA, 2010) for Chinese manufacturers.

4. Wind turbine manufacturers and innovation system functioning

In this section, we analyse China's innovation system functioning, structured according to the seven innovation system functions (Table 2). We focus on the interplay between the environment created by the Chinese TIS and operations of individual turbine manufacturers, and how this affects export opportunities.

4.1. Knowledge development

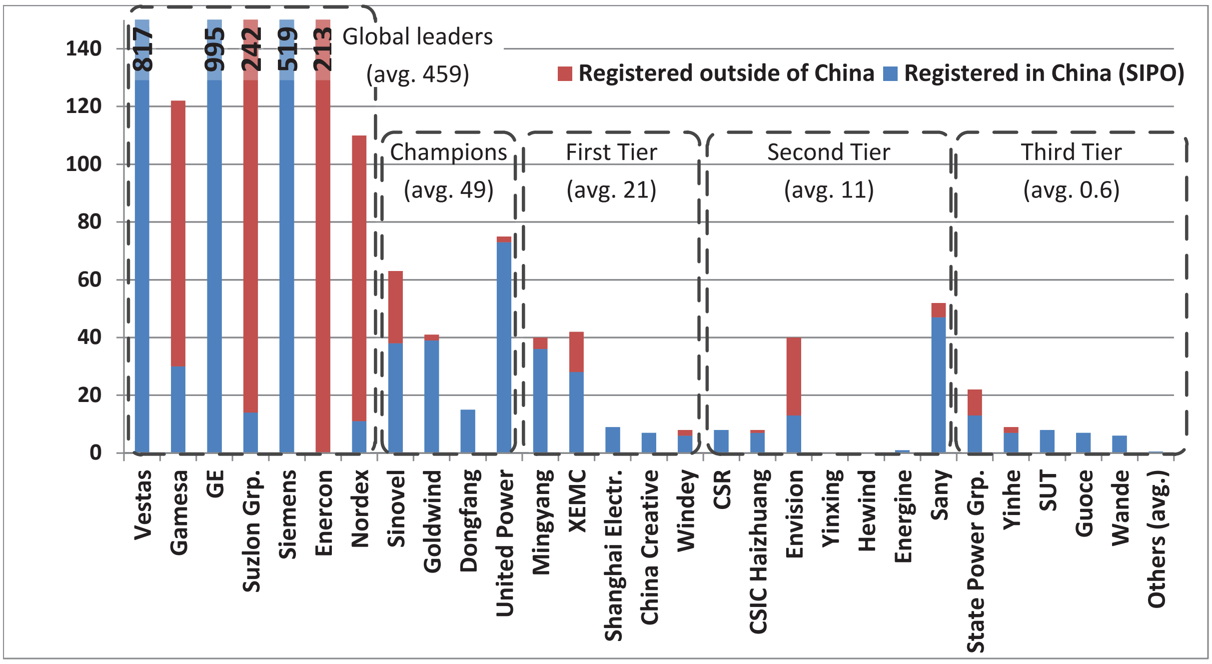
The development of new knowledge is central to the functioning of innovation systems (Hekkert et al., 2007). We can use patenting activity to assess innovativeness in a certain technological field or country (Bergek et al., 2008b). On the national level, Chinese activity for wind power technologies has quickly risen in recent years. In 2011, 2,600 patents were granted (globally) to applicants from China, compared to 3,044 for the EU-15 or 1,234 for the US (EPO, 2012; SIPO, 2012).

Patents numbers granted to Chinese turbine manufacturers, however, have not seen such a spectacular growth. Globally leading turbine manufacturers registered several hundred patents over the years 2010 to 2012, compared with several dozen patent grants, at most, for Chinese competitors (Figure 3). Between Chinese manufacturers, average patenting activity corresponds with tier level. Sany and Envision are the only firms that really stands out. Sany is China's largest heavy machinery and power generation equipment manufacturing conglomerate. As such it has plenty of experience in related engineering fields, and plenty of resources to spend on R&D activity. Envision has R&D centers in Denmark, China, Japan and the US as well as collaboration centres with a number of Chinese universities. Unlike most manufacturers, it has started operations based on an independently developed turbine design. Sany and Envision are rather recent entrants into the wind turbine sector, however, and haven't been able to benefit from recent market growth much. The Institute of Wind Energy, Shenyang University of Technology (SUT) is grouped into Tier 3 on the basis of installed wind turbines, but its primary business is the supply of technology to other firms.

State funding for R&D is arranged via the creation of 'State key laboratories' and through grants of government research programmes. The establishment of a State key laboratory means a firm will receive state funding for an undetermined period of time, subject to annual evaluation. Some key labs have a research theme, i.e. offshore wind power. State key labs are usually established within universities or the Chinese academy of Science. In the wind power sector, state key labs have been established mostly at the manufacturers, as these are expected to be better able to commercialise products than academic institutions (UNIDO, 2010). Currently, wind power related State Key labs are established in the manufacturers Sinovel, Goldwind, United Power, XEMC and Windey, as well as one at SUT.

Annually returning research programmes that include wind power are the National High-tech R&D programme ('863') and the National S&T support programme. Grants from the 2012 '863' and S&T support programme were awarded to Sinovel, Goldwind, United Power and Windey (MOST, 2012b, c). Although other manufacturers will be receiving R&D funding from provincial or local level governments, state support is directed nearly entirely towards the national champions.

Figure 3. **Patent grants to wind turbine manufacturers (sum of grants 2010-2012)**



Notes: Patent grants for IPC Class F03D (Wind motors). Data for patents registered in China from (SIPO, 2012); China has three different types of patents, data for China include invention patents only, as these are considered most comparable to patents outside of China (Hu and Jefferson, 2009). Data for Goldwind includes patent grants to subsidiary Vensys, XEMC includes grants to subsidiary Darwind. Data for patents registered abroad from esp@cenet (EPO, 2012). 'Others (avg.)' includes 49 more firms.

4.2. Knowledge diffusion

On a global level, China's wind industry has formed relatively late. With the exception of Goldwind, Windey and Dongfang, no Chinese manufacturer was engaged in wind turbine manufacturing before 2005. By then, the global wind industry had already reached a level of relatively technological maturity. Chinese firms that ventured into wind turbine manufacturing have regarded the quickest or best route to a marketable product to be a licensing deal or partnership with an experienced, foreign, turbine designer. Virtually without exception, Chinese manufacturers have started operations with such a technology supplier. Progressive experience and investment may lead to further in-house development of those technologies.

The benefit of transfers of foreign knowledge for the development of the domestic industry has long been recognized by the Chinese government, which has encouraged it from the outset of wind power utilization in China. For example, in the earliest attempts to create a domestic turbine manufacturing industry, two Joint Ventures were created between foreign and domestic manufacturers, in order to promote knowledge spill-overs (the so-called 'Ride the wind' plan; SPC, 1997). Between 2003 and 2009, wind farm development permits were conditional on a minimum percentage of local manufacture used (NDRC, 2003, 2009a). Foreign manufacturers could comply only with these requirements by opening production capacity in China, which further encouraged opportunities for knowledge spill overs. Between 2006 and 2011, a number of manufacturers received financial assistance from the Global Environment Fund and the NDRC, to develop multi-MW wind turbines in cooperation with foreign technology partners (the 'Renewable Energy Scale-up Program'; CRESP, 2012). Currently, the policy focus is on the domestic development or control over key technology (see Table 1).

We can differentiate between different mechanisms for turbine design with regard to technological capabilities. The use of a technology license indicates that a firm's in-house capability for turbine design is weak, whereas cooperative development, and later on independent development, indicates increasing technological competence. The development of Chinese manufacturers through these three phases of turbine design is presented in Table 4.

Many Chinese manufacturers, especially the Champions and First Tier firms, are independently developing turbines by now (Table 4). Although quite some Third Tier firms claim independent development, the industry experts that we interviewed were sceptical of these claims. The bulk of these firms assembles rather than manufactures turbines, with the independent designs being mostly a guide to assemble components sourced from suppliers. This would be more in line with the near absence of patents filed by firms in this Tier.

There are also a number of manufacturers that use technology licenses from domestic suppliers, especially from the Wind Energy Technology Institute of Shenyang University of Technology (SUT). At least 17 Third Tier firms work on the basis of a technology license from SUT (CWEEA, 2010). Only three firms (Sany, New United and Sharpower) have yet managed to put this design into serial production, however (CWEA, 2012a; CWEEA, 2010). China Creative is spin-off firm of SUT. An engineer at SUT that we interviewed did indicate that they had no license deal, or any expectation to such a deal, with any foreign partner. As far as we are aware, none of the Chinese manufacturers has managed to license its technology to any foreign partner so far.

Table 5. Technological mechansim for turbine development; different manufacturers

	Name	Est.	License	Cooperative	Independent
Champions	Sinovel	2005	2005 (Fuhrlander)	2007 (Windtec)	2009
	Goldwind	1998	1998 (Jacobs)		2008 (Vensys)
	Dongfang	2004	2004 (RePower)	2010 (Windtec)	
	United Power	2007		2007 (Aerodyn)	2012
1st Tier	Mingyang	2006	2006 (Aerodyn)	2010 (Aerodyn)	
	XEMC	2006	2006 (Zephyros)		2009 (Darwind)
	Shanghai Electric	2006	2006 (DeWind)	2009 (Aerodyn)	2010
	China Creative	2006			2006
	Windey	2001	2001 (RePower)	2006 (RePower)	2009
2nd Tier	CSR	2008		2010 (Windtec)	
	CSIC Haizhuang	2006	2006 (Frisia)	2010 (Aerodyn)	
	Envision	2008			2008
	Yinxing	2007	2007 (Mitsubishi)		
	HEwind	2005	2005 (Goldwind)	2007 (Aerodyn)	
	Energine	2005	2005 (Acciona)		2011
	Sany	2008		2008 (SUT)	2009
3rd Tier	18 firms				
	4 firms			Various	
	32 firms		Various		

Note: Most firms have more than one turbine model, which may have been developed in different mechanisms; the data included refers to the biggest capacity model. Years indicate the first time firms developed a turbine using each respective mechanism. Names in brackets refer to the technology suppliers or partners. Goldwind and Darwind acquired Vensys and Darwind and thus integrated tech development previously done by a foreign partner into their own operations.

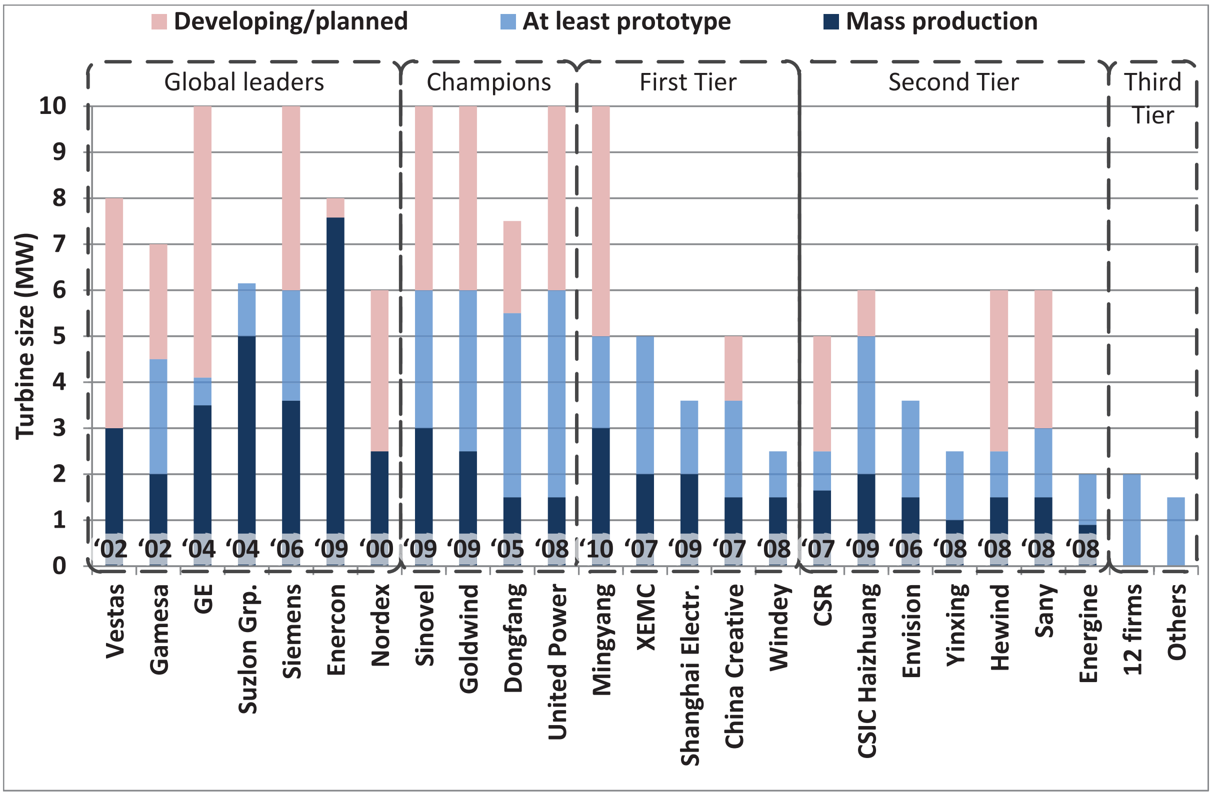
4.3. Guidance of the search

A long standing trend in the global wind turbine industry is that of unit scale increases. State of the art turbines were several hundred kW in the early nineties; MW sized in the late nineties and multi-MW turbines became available since the turn of the millennium (Ackermann and Söder, 2002). The benefits of bigger turbines are that they are more efficient (they can extract more energy from the same wind resources), and they may lower installation and maintenance costs (when compared with several smaller turbines), although they are more challenging to engineer (EWEA, 2011b). High capacity turbines are more economical especially with high land prices or challenging installation conditions, for instance in offshore wind farms.

The global leaders have all developed multi-MW turbines circa during the first half of last decade, and are working on further scale increases, especially for the offshore segment (Figure 4). Chinese manufacturers have long trailed this development, but are catching up fast. By year end 2008, only one Chinese manufacturer (XEMC) had installed turbines larger than 1.5 MW (CWEA, 2012a). In just several years since then, manufacturers across the board have developed a turbine of around 3 MW, and many are developing turbines with a capacity of around 5 MW, comparable to or bigger then what the global leaders have (Figure 4). These are all prototypes, however; some of these have a first unit installed at a test farm, others have only just rolled of the production line (company wesites; CWEA, 2012a).

Four Chinese manufacturers have even announced a 10 MW offs-shore model. This is part of the governments' ambition in the 12th Five Year Plan (Table 1). Market analysts interviewed for this study assessed this to be a matter of national pride and were sceptical of market demand for such machines in the near future. This is corroborated by criticism of China's largest developer (Longyuan) of Sinovel's reckless development of their 3MW off-shore turbine and ensuing poor operational performance (People's Daily, 2011).

Figure 4. **Development of turbines offered by different manufacturers (unit capacity; MW)**



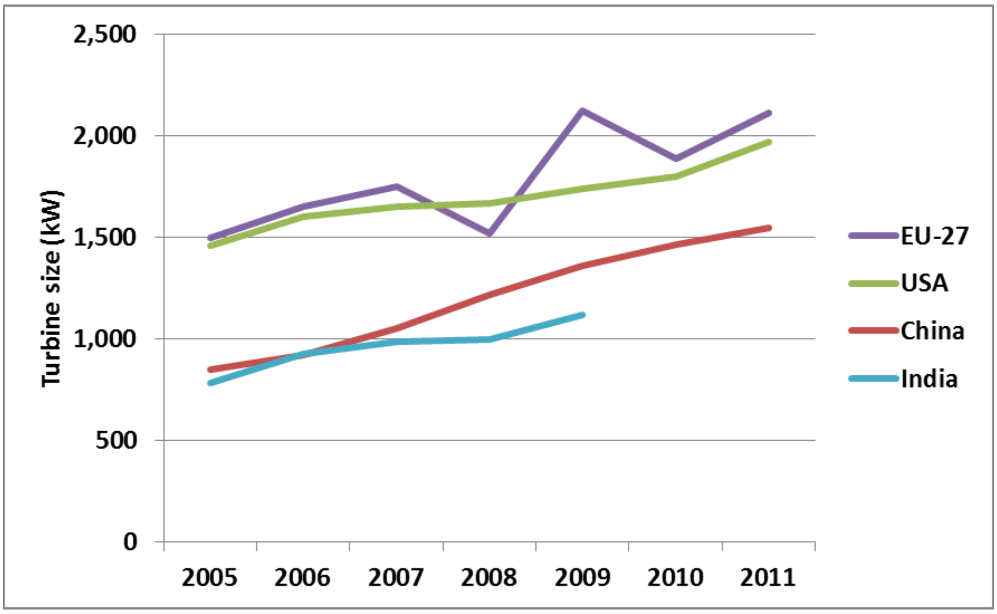
Notes: Indicates the largest capacity turbine in each phase of development. 'Mass production' means at 50 MW of that model installed by year end 2011; Years in each column indicate when the model in mass production was first installed; sources: (company websites, CWEA,2012a; CWEEA, 2010). Vestas has been developing an off-shore model of 7 or 8 MW for several years now, but prototype testing has been pushed back to 2014. Enercon developed a 6 MW turbine in 2007 and upgraded it to 7.58 MW in 2009.

The Chinese manufacturers may have difficulties attracting a lot of market demand for these very large capacity turbines, however, especially in the domestic market. The Chinese market remains focused on turbines of around 1.5 MW. Out of a total of 11,400 turbines installed in China in 2011, only 213 were of a capacity of 2.5MW or above. Average unit capacity was slightly over 1.5 MW, compared to 2 MW in US and EU markets (Figure 5). Annual reports of manufacturers with the largest penetration in the multi-MW class segment indicate that orders for turbines of up to 3 MW are gaining pace, but this is not the case for their largest of turbines (Table 5).

The current policy and market environment in China does not strongly stimulate much further scale increases. China's wind resource rich areas have abundant low priced land available, which means higher numbers of low capacity units are more economical. Very large turbines are especially suited to off-shore wind farms, but China's offshore developments are progressing only very slowly. European off-shore wind farms, which currently encompass nearly all the worlds offshore installations, were at 4.3 GW of fully functional farms by mid-2012, with another 3.7 GW under construction (EWEA, 2012a; GWEC, 2012c). By comparison, Chinese offshore installations are at 258 MW, in 'demonstration' farms of the coast of Jiangsu (Rudong) and Shanghai (Donghai). These farms include 50 MW of turbines from Siemens, the remaining 200 MW are of Sinovel's 3MW model (CWEA, 2012a).

Although China's recent 12th Five-Year-Plan for renewable energy stipulates ambitious goals of 5 GW of offshore installations by 2015 and 30 GW by 2020, developments have lagged behind schedule (NEA, 2012). An initial tender in 2010 awarded four development permits for offshore projects totalling 1 GW of installations. A second round of tenders was planned to be held in 2011, but has been postponed for an undetermined period of time. Discussion on the siting of offshore farms between different government agencies has meant that none of the parks included in the first tender has started construction, and a resolution is still pending (ERI, 2012). This means that there is a lack of testing grounds for Chinese brand high capacity and offshore turbines, stalling their further development. This also stalls their build-up of operational history, which will seriously hamper their chances in export markets.

Figure 5. **Average turbine size, key global markets**



Notes: Turbine size of newly installed capacity in that year. Sources: (CWEA, 2012c; EWEA, 2011a; 2012c; Wiser and Bolinger, 2012)

Table 6. Order backlog for key Chinese manufacturers of high capcity turbines

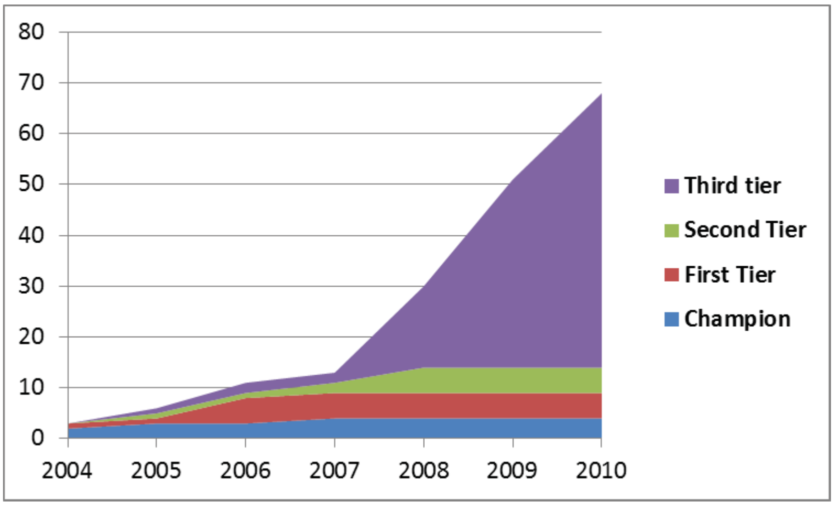
Manufacturer	Order backlog (nr. of turbines)						Avg. size (MW)
	1.5 MW	2 MW	2.5 MW	3 MW	5 MW	6 MW	
Sinovel	2,415	0	0	422	1	0	1.72
Goldwind	2,575	0	384	5	0	0	1.63
Mingyang	1,136	123	0	67	0	1	1.63

Source: company 2012 half year/Q3 reports

4.4. Entrepreneurial activities

The strong growth of the Chinese market for wind power equipment has attracted many new entrants. By 2005, only six Chinese firms were engaged in wind turbine manufacturing. This number has been growing rapidly since 2008 (Figure 6), as many firms hoped to capitalize on fast growing turbine demand. The State Council already warned that this could lead to an overheating industry in 2009 (State Council of P.R. China, 2009). In 2011, Wind power installations were at 17.6 GW, whilst production capacity had exceeded 30 GW (CWEA, 2012b; CWEA, 2012c). In 2012, wind power installations dropped to 14.0GW, whilst production capacity climbed to 37 GW or more (BTM Consult, 2012). The sheer number of manufacturers is part of the cause of the overcapacity, but the problem is exacerbated by the increasingly large sizes in which wind farms are developed (more in section 0). In order to compete for equipment tenders that come in batches of several GW simultaneously, firms need to have sufficient manufacturing capacity available. Further, some local governments have introduced ‘localization rates’, awarding projects to manufacturers on the precondition that these set up manufacturing capacity for local employment (CWEA, 2012b).

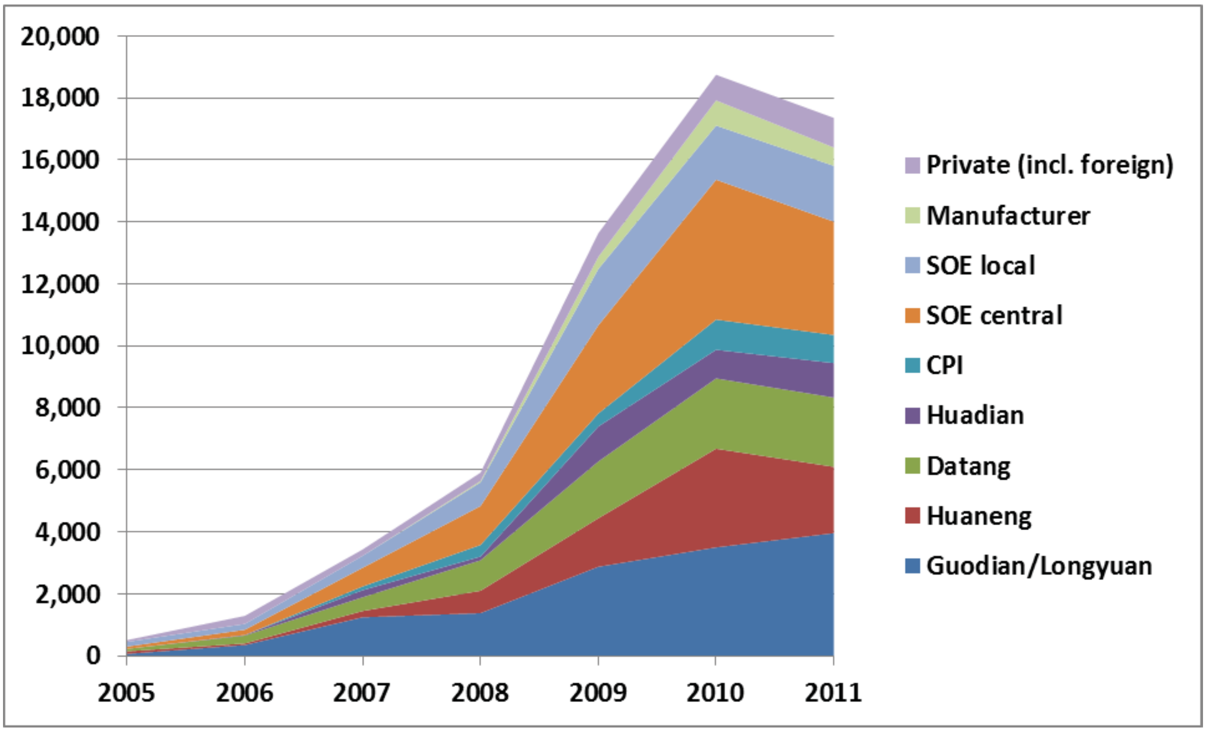
Figure 6. Date of entry of manufacturers



Note: Source: (CWEEA, 2010, company wesbites)

The customer base for wind turbine manufacturers, i.e., the wind farm developers, has also changed considerably in recent years, although not in terms of total numbers. Historically, the most important developer is Longyuan. This state owned enterprise was established in 1993 as an asset of the (former) Ministry of Electric Power, with the mission to research and develop renewable energy technologies. In 2002, China reformed its electrical power market. The State Electric Power Corporation was abolished and its assets divided over five separate utilities: China Power Investment (CPI), Datang, Guodian, Huadian and Huaneng. These are now known as the 'Big 5' power companies, and remain SOE of the central government. Simultaneously, Longyuan was incorporated as a subsidiary of Guodian. In 2007, the NDRC officially mulled a long expected Renewable Portfolio Standard (RPS) of 3% of non-large hydro renewables in generation capacity by 2010 and 8% by 2020 (NDRC, 2007). These obligations apply to any power company with more than 5 GW in total generation capacity. The 'Big 5' have since led investment in wind farm development. Collectively, they operate 58 per cent of China's wind farms (cumulative capacity by year end 2011). Other SOE, mostly utilities under central or provincial government control, operate another 32 per cent (Figure 7).

Figure 7. **Wind farm developers by annually installed capacity (MW)**



Notes: Longyuan/Guodian, Huaneng, Datang, Huadian and CPI are the so-called 'Big 5' power companies that were created with the abolishment of the State Electric Power Corporation in 2002. 'Manufacturer' refers to turbine manufacturers that have invested in wind farm development. Source: (CWEA, 2012a).

With the large number of turbine manufacturers, utilities should be able to choose from a long list of submissions when they organize a tender for turbine supply contracts. A number of wind farm developers, however, have had preference for one turbine supplier, due to (partial) ownership of the turbine manufacturer (Table 6). Such chain integration may help reduce investment or improve the value added for wind farm developers (Accenture, 2012). In recent years especially, an increasing number of developers is formalizing its relationship with turbine suppliers (Table 6). Collectively, the developers with formal connections with a turbine manufacturer operated 61.1 per cent of all wind parks in China (year end 2011). As many of these relationships were formed relatively recently, the impact on supplier preference is yet to unfold. What is clear, is that part of the market is not subject to entirely open competition between turbine manufacturers, and that this part of the market is set to increase in size in coming years.

The relation between Longyuan, China's largest developer, and manufacturer United Power is perhaps the most relevant example. Longyuan used to have a very diversified portfolio of suppliers, but has recently largely shifted towards United Power. In 2009, Longyuan started preparations for future off-shore development with a 32 MW intertidal test-farm in Rudong, Jiangsu province. It installed 16 turbines of 8 different manufacturers (Envision, Goldwind, Mingyang, SANY, Sinovel, Shanghai Electric and United Power). It remains to be seen whether operational performance of these different turbines will affect Longyuan's future choice of off-shore turbine supplier, or whether its connections with United Power will overrule such considerations.

Table 7. Formal relationships between wind farm developers and turbine manufacturers

<table>
<tr><th>Developer</th><th>Wind farms in operation</th><th>Turbine manufacturer</th></tr>
<tr><td>Longyuan & Guodian</td><td>13,604 MW (21.8%)</td><td>United Power</td></tr>
<tr><td colspan="3">• Longyuan is China's first and largest wind farm developer. It operated 60 per cent of China's wind farms in 2000. Longyuan became a subsidiary of Guodian with the abolishment of the State Electric Power Corporation in 2002
• Guodian established its subsidiary 'Guodian United Power' in 2007 for the manufacture of turbines
• 89 % of United Power's cumulative sales (year end 2011) were towards Longyuan and Guodian.</td></tr>
<tr><td>Huaneng</td><td>7,964 MW (12.8%)</td><td>Sinovel</td></tr>
<tr><td colspan="3">• Huaneng has purchased three times more turbines from Sinovel then from any other manufacturer, and is Sinovel's biggest customer (CWEA, 2012a). Huaneng has also been the top customer for Sinovel's 3 MW model (ibid), and is currently in negotiations over an off-shore project using 17 units of Sinovel's 6 MW turbine (Xinhua, 2012).
• A company spokesperson explained Sinovel's success with Huaneng as due to 'good relations', although no formal connections, e.g., in ownership, could be identified. Sinovel was a cornerstone investor for $30 mln in Huaneng Renewables' IPO, citing 'good cooperation' (Xinhua, 2011).</td></tr>
<tr><td>Huaneng</td><td>7,964 MW (12.8%)</td><td>Mingyang</td></tr>
<tr><td colspan="3">• On Aug. 31st 2012, Huaneng Renewables and Mingyang established a Joint Venture for development of wind farms both domestically and overseas (company website).
• Nearly 40 per cent of Mingyang's 2011 sales were towards Huaneng (CWEA, 2012a)</td></tr>
</table>

<table>
<tr><th>Developer</th><th>Wind farms in operation</th><th>Turbine manufacturer</th></tr>
<tr><td>Datang</td><td>7,937 MW (12.7%)</td><td>China Creative</td></tr>
<tr><td colspan="3">• Datang bought a 70 per cent stake in China Creative in august of 2011 (SASAC, 2011)
• 43 % of China Creative's 2011 sales were towards Datang (CWEA, 2012a)</td></tr>
<tr><td>Datang</td><td>7,937 MW (12.7%)</td><td>XEMC</td></tr>
<tr><td colspan="3">• XEMC's wind branche is a Joint Venture between Datang, which invested 30% and XEMC, which owns the remaining 70% (company website).
• 45 % of XEMC's cumulative sales (year end 2011) were towards Datang (CWEA, 2012a).</td></tr>
<tr><td>China Guangdong Nuclear</td><td>2,911 MW (4.7%)</td><td>Mingyang</td></tr>
<tr><td colspan="3">• China Guangdong Nuclear (CGN) and Mingyang, also from Guangdong province, established a Joint Venture in Sept. 2011, focusing on off-shore and overseas developments (company website).</td></tr>
<tr><td>Tianrun</td><td>1,349 MW (2.2%)</td><td>Goldwind</td></tr>
<tr><td colspan="3">• Tianrun is subsidiary of Goldwind, and exclusively uses Goldwind turbines (CWEA, 2012a)</td></tr>
<tr><td>Three Gorges Corporation</td><td>1,092 MW (1.7%)</td><td>Goldwind</td></tr>
<tr><td colspan="3">• The Three Gorges Corporation holds 31 per cent of Goldwind shares (company annual report)
• 68 % of all Three Gorges Corp. installations are with Goldwind turbines (CWEA, 2012a)</td></tr>
<tr><td>Ningxia Electric Grp</td><td>1,073 MW (1.7%)</td><td>Ningxia Yinxing; Nordex-Yinchuan</td></tr>
<tr><td colspan="3">• Ningxia Yinxing is a subsidiary of Ningxia Electric Grp.; Nordex-Yinchuan is a JV between the Danish manufacturer and a subsidiary of Ningxia Electric Grp. (Company website)
• All of Yinxing's sales and 47% of Nordex-Yinchuan's sales were towards Ningxia Electric Grp. (CWEA, 2012a).</td></tr>
<tr><td>CECEP</td><td>895 MW (1.4%)</td><td>Windey</td></tr>
<tr><td colspan="3">• The China Energy Conservation and Environmental Protection Grp. (CECEP; previously CECIC) purchased a controlling share in Windey in 2006 (MOFCOM (Zhejiang prov.), 2006)
• 32 % of Windey's cumulative sales (year end 2011) were towards CECEP (CWEA, 2012a)</td></tr>
<tr><td>State Grid</td><td>880 MW (1.4%)</td><td>State Power Grp.; Xuji Grp.</td></tr>
<tr><td colspan="3">• The State Grid is China's largest grid company. The State Grid is a non-controlling shareholder of the State Power Grp. (company website) The State Grid acquired full ownership of XuJi Grp. in Jan. of 2010 (company website)
• 58 % of State Power Grp.'s and all XuJi Grp.'s 2011 sales were towards the State Grid (CWEA, 2012a)</td></tr>
<tr><td>XEMC New Energy, Tianwei, Changxing, Ruihao, Tiandi</td><td>402 MW (0.7%)</td><td>XEMC, Tianwei, Changxing, Ruihao, Tiandi</td></tr>
<tr><td colspan="3">• Turbine manufacturers that have developed wind farms, comparable with Tianrun-Goldwind</td></tr>
</table>

4.5. Market formation

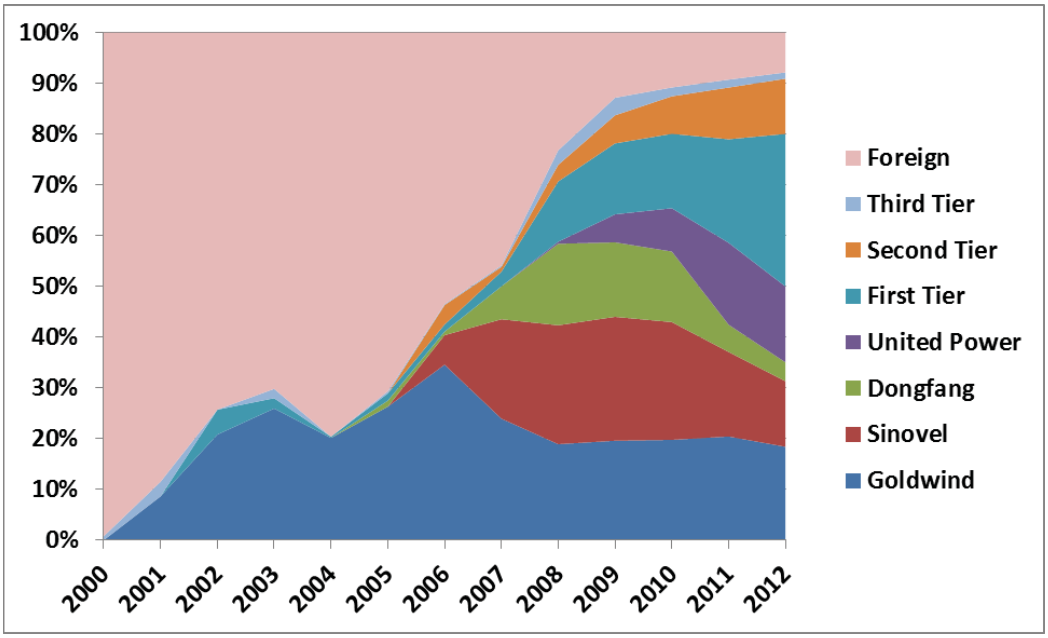
4.5.1. The domestic market

The Chinese wind turbine market has been the largest globally since 2010 (Figure 1). Although annual installations have grown very rapidly in the past few years, these have now reached a plateau. Installations were at 18.9 GW in 2010 and 17.6 GW in 2011, but down to 14.0 GW in 2012 (CWEA, 2012b). The level of additions in 2012 is consistent with China's latest policy goal of 100 GW by 2015, and 200 GW by 2020 (NEA, 2012). The most optimistic of forecasts predict installations of between 15 to 18 GW annually for the coming few years, possibly picking up to 20 GW annually towards the end of the decade (overview of forecasts from CWEA, GWEC, CREIA and BTM, as reported in CWEA, 2012a).

One reason for this 'slowdown' is that the central government has reclaimed much control over wind farm development. Permitting authority for wind farms up to 50 MW is in the hands of provincial governments, and most of China's wind farms have been developed in 49,5 MW sections to avoid slower permitting procedures of the central authorities. This has, amongst others, created problems with grid connection, as it was difficult to plan where additional grid capacity was needed. With the introduction of national feed-in-tariffs (FIT), in mid 2009, newly planned wind farms are eligible to receive FIT premiums only after the central government's NDRC approval (NDRC, 2009b). The central government now has more control over location and speed of developments.

The most obvious trend within the Chinese market is the reduced dominance of foreign manufacturers in favour of domestic brands (Figure 8). The national Champions especially witnessed very rapid growth, with Sinovel, Dongfang and United Power reaching an annual output of several GW only a few years after their market entry (CWEA, 2012a).

Figure 8. **Turbine manufacturers' share of the Chinese market (annual additions)**

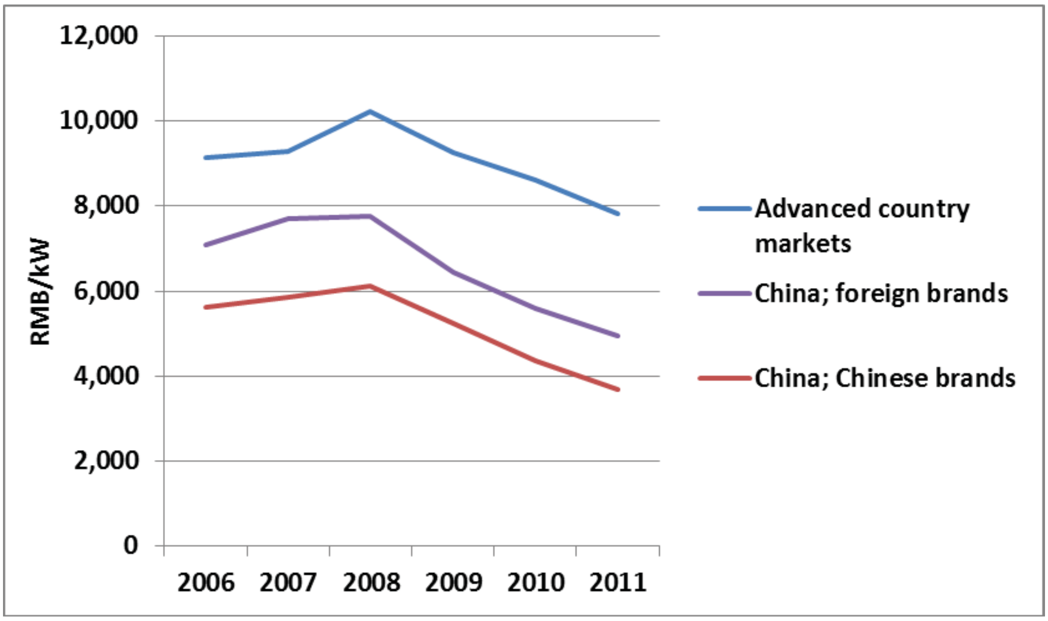


Source: (CWEA, 2012a, with 2012 update for top 20 manufacturers)

One explanation for the success of Chinese manufacturers versus their global competitors in the home market is the dominance of state owned enterprises in the energy sector, and wind power development in particular. There are currently no concrete regulations that obligate procurement of domestic equipment, but there is a clear political desire to nurture the domestic wind turbine industry in China's policies. The management of state owned enterprises will be evaluated, amongst others, on how well the enterprise has followed government objectives for the sector. Active participation in achieving policy goals for the wind power sector will also increase the enterprises' political clout in policies and permitting procedures for the thermal power sector.

A second reason for the success of Chinese manufacturers has been their ability to compete on turbine price. Chinese manufacturers have been able to offer turbines at lower prices than their foreign competitors, even though these foreign competitors have manufacturing plants within China (Lewis, 2012; figure 9). This is largely due to the localization of component manufacture. Historically, much components needed to be imported, but the supply chain in China is increasingly able to satisfy local demand, with the exception of highly specialized steel components used in axle and yaw bearings (CWEA, 2012b; Han et al., 2009). Markets for converters and control systems are still dominated by foreign brand names, but these have manufacturing capacity in China (CWEA, 2012a, b). Manufacturers may choose e.g., generators, blades and gearboxes from local component manufactures or in-house production. There is a gap in quality between Chinese component manufacturers and the global leaders, but this difference is offset by a far larger price gap. The pressure to reduce cost has also led foreign turbine manufacturers to adopt larger shares of Chinese brand components for the Chinese market.

Figure 9. **Turbine prices in China and advanced country markets**



Notes: 'Advanced country markets" is average for the US, Denmark, Germany and Spain (weighted by market size). Source: combination of (EWEA, 2011a; IEA Wind, 2012; Lewis, 2012, 2011 update from CWEA).

The pressure to compete on turbine price has a number of causes. The large number of competitors and manufacturing overcapacity creates steep competition over market share.

The leading customers in the Chinese market, i.e., the wind farm developers, face incentives that favour less costly turbines at the expense of turbine quality. First, the obligatory Renewable Portfolio Standards (RPS) for the large utilities are measured in generation capacity (kW of turbines installed), not in energy usefully employed (kWh of electricity used). Effectively, RPS can be fulfilled with the installation of a number of wind turbines, regardless of the amount of electricity they deliver to the grid. The race to develop wind farms with seemingly little regard for profitably became apparent in earlier rounds of wind power concessions. Construction permits in these concessions were awarded to the developer that asked for the lowest power price premium. Prices bid were too low to be able to make a profit (Li et al., 2010). The introduction of nationally determined feed-in-tariffs did away with this irrational competition over developments for on-shore parks, but the same mechanisms is now used for off-shore parks. Power purchase prices in the bids for development permits were in the range of 68 to 78 RMB/MWh; more than the FIT for onshore developments, whilst installations costs at sea may be two to three times as high (IEA/ERI, 2012).

There is also strong competition over land with the best wind resources; a 'land grab' in the words of one interviewee. Leases last for 70 years, but farms need to be developed within two years to secure these rights. Long term renewable energy strategy means power companies must secure sufficient lands now. With very low turbine prices, some losses in turbine operational life and power output for the first few years of the lease are acceptable.

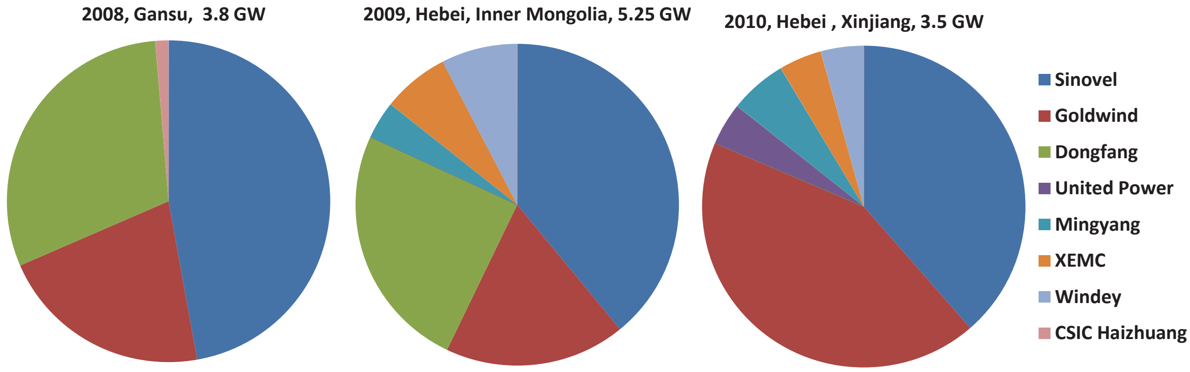
There is a further lack of incentive to focus on the production of useful electricity by reduced profitability of wind power generation. The pace of wind farm development is not matched by power grid companies. Chinese installations totalled circa 45 GW by year end 2010, but the total of grid connected and operating wind farms only reached 45 GW by year end 2011 (Shi, 2012). This also means that up to 14,5 GW, or 25 per cent of wind farms was not connected nor generating revenue yet by the end of 2011.

Power companies have also been unable or unwilling to utilize the power generated by wind farms that are connected to the grid, because of the intermittency of their power output and concentration in regions with relatively low power demand. In cases of surplus supply, wind farms get disconnected from the grid. Collectively, Chinese wind farms produced 72.3 TWh of power in 2011 (IEA Wind, 2012). Total curtailment was 12.3 TWh, or 16.8% countrywide, with levels of curtailment reaching 23% in regions with high concentrations of wind farms (CWEA, 2012b; Shi, 2012). This means a loss of revenue of 6.6 billion RMB in power sales (Shi, 2012), and a further 0.87 billion RMB in foregone carbon credit revenue (assuming €9/tonne CO2-eq; UNEP/Risoe, 2012). The situation only worsened in 2012, to 20 TWh of curtailment, with a value of around 10 billion RMB in power sales (Qin Haiyan, secretary general of the CWEA, as quoted in Windpower Monthly, 2013). Foregone CDM revenue was 0.78 billion RMB, with carbon prices at an all-time low of €5/tonne CO2-eq (UNEP/Risoe, 2012).

With this, there is little incentive to pay premium prices for turbines with very high availability (low nr. of days offline for maintenance), or very high efficiency (high conversion of wind resources into power output).

This tendency is further exacerbated still in so-called 'concentrated equipment tenders' for China's wind bases. These bases are a total of eight regions that have been selected to develop at least 10+ GW of wind power each. Permits for these wind bases are awarded for wind farms of 100 to 300 MW each, with tenders offered in batches of several GW simultaneously (Figure 10). The tendering process is overseen by the central government's NDRC. Tenders for developers are separate from the tender for equipment manufacturers, with developers obligated to use the turbines from the winner of the equipment tender. In order to participate in the tender, the turbine model offered must have at least 100 MW installed and running for 240 hours. Other than that, price per kilowatt is the only selection criterion. Three tender rounds totalling 12.55 GW were held between 2008 and 2010; winners are presented in Figure 10. The concentrated equipment tenders have been dominated by the National Champions, to a larger extent than the market segment outside these wind bases. These are the only manufacturers with sufficient scale of operations to reduce prices for these large orders even further.

Figure 10. Outcome of wind base equipment tenders



Source: (collected news items from China Wind Power Net, 2013; CWEA, 2012a)

This competition has led to a race to the bottom for turbine prices. The senior management of Sany, a large heavy machinery conglomerate that has relatively recently entered the wind turbine business, criticised China's system for equipment tenders as qualities such as power output, maintenance needs and operational safety have become secondary concerns (Wu and Li, 2012). This has furthermore led to unhealthily small profit margins and neglect for R&D for product development (ibid). The same line of argument was reiterated by Wu Gang, president of Goldwind, Han Junliang, president of Sinovel, and Zhang Binquan, general manager of United Power, in a forum at the China Wind Power 2012 conference (CWP 2012 conference, 2012).

Annual reports from publicly traded turbine manufacturers already reveal reduced revenue, and even sharper reductions in profit (0). The pressure created on R&D budgets is apparent from Goldwind's decision to reduce 2011 R&D expenses by 59 per cent from the planned budget for that year (company annual report). Similarly, Sinovel has scrapped recruitment plans for 350 new employees, mostly R&D personnel (Xinhua News, 2012)

Table 8. Financial performance of wind equipment manufacturers 2010-2012

	Revenue (mln RMB)			Profit (mln RMB)		
	2010	2011	2012; Q2	2010	2011	2012; Q2
Chinese firms						
Goldwind	17,475	12,756	3,484	2,799	864	112
Sinovel	20,325	10,436	3,086	3,133	529	101
Mingyang	5,518	5,516	1,203	763	454	84
Energine	607	335	202	100	11	31
Yinxing	842	658	/	63	21	/
HEwind	872	613	/	112	69	/
Global leaders						
Vestas	60,481	51,240	58,810	4,090	-334	33
Gamesa	24,157	26,630	10,962	1,040	1,150	-48.9
Suzlon Grp.	25,056	28,250	16,481	-1,584	-661	-1,447
Nordex	8,809	8,139	3,549	350	-261	-107

Notes: Profit is earnings before interest and taxes. Includes all Global leaders, National Champions, First and Second Tier firms with public financial reports, with separate figures on wind power equipment for non-pure wind power manufacturers. Source: company annual reports. Vestas, 2012 is full year

4.5.2. Export markets

Faced with production capacity that exceeds domestic demand, a further contracting domestic market and dwindling profit margins, Chinese manufacturers are looking to export markets to improve their financial performance, although success has been limited so far. In 2011, only 220 MW, or just 1.35 per cent of instalments occurred abroad, although a number of manufacturers are negotiating more foreign projects (CWEA, 2012a; CWEA, 2012b). Part of the problem is that the relative cost advantage Chinese turbines largely evaporates with transport costs to distant markets.

The quest for foreign market share is also poorly timed, as global markets are in downturn as well (see global turbine prices and financial performance of global leaders in Figure 9 and 0). The outlook for the US market is gloomy as uncertainty about extension of financial support for wind power ('producer tax credits') lasted so long that developers could not plan installations for 2013 and after with any confidence. As a result, installations are predicted to slump to 1 to 2 GW, down from 13.1 GW in 2012 (EIA, 2012). The European market is slowing down as well. Record low carbon prices are reducing the incentive to invest in wind power, and austerity measures include reduced support for wind power especially in Spain, Portugal and Italy, a number of the growth markets in Europe (EWEA, 2012b; GWEC, 2012b). A number of Emerging Economies, in South America, South-East Asia and Africa are expected to grow, but likely at a rate of about 5 GW annually up to 2015, for those three regions added together (GWEC, 2012b). Even a significant market share here would not offset reduced demand in the domestic market.

4.6. Resource mobilization

Chinese turbine manufacturers and wind farms developers have had little problems in securing finance for the last several years. This has led to ‘blind and duplicative investment’ in the sector, leading to manufacturing overcapacity (State Council of P.R. China, 2009). Power companies used to have sufficient funds available for wind farm development, but this has changed in recent years. The profitability of thermal power generation has decreased with rising coal prices but electricity prices at fixed, government determined levels (Yang et al., 2012). Further investment in wind farm development may be hampered by the lesser financial performance of the utilities’ core business (GWEC (Global Wind Energy Council), 2012a).

Finance for projects with Chinese turbines is less easily accessible in export markets than it is in China. Due diligence requires sufficient information on operational performance. Many Chinese turbine models, especially the larger and offshore models, are rather new products, with little track record. There is furthermore no independent auditing of operational performance of turbines installed in China, increasing (perceived) investment risk. The current poor outlook for China’s domestic market and financial performance of turbine manufacturers aggravate the problem. Turbine sales include long warranty and maintenance contracts. Increasing uncertainty as to what firms will survive the coming industry shake-out increase risk associated with the fulfilment of such contract obligations.

Specific difficulties with foreign finance exist for Sinovel, which is being sued by American Superconductor. AMSC claims Sinovel illegally acquired its control system software and is seeking $1.2 bln in damages. Developers are cautious about being included in legal disputes when using Sinovel turbines, and may fear the effects that the litigation may have on firm survivability. The Brazilian developer Desenvix agreed to buy Sinovel’s turbines only after sufficient proof that turbines included components and software acquired from different sources (Financial Times, 2012). Ireland based Mainstream Renewable Power had a MoU with Sinovel to develop 1 GW of wind parks in Ireland, but has since indicated it will seek an alternative equipment suppliers as a result of the dispute (company website, Recharge News, 2012).

Finance for projects with Chinese turbines may be supported by the China Development Bank (CDB), which is tasked with assisting Chinese firms’ foreign expansion. The Brazilian developer Desenvix indicated that CDB funding was a critical factor in its choice for Sinovel turbines.

The CDB further has an agreement with Goldwind for a $6 bln credit line, $5 bln for United Power/Longyuan to develop wind farms in Pakistan, and $3 bln for the Beijing Construction Engineering Group, to develop a wind farm in Argentina using Chinese turbines (Bloomberg, 2012, company websites). These credit lines could help especially in Emerging Economies in South America, South-East Asia and Africa, where local finance is less easily available. CDB credit lines are no guarantee for the development of projects, however. Finance analysts and project managers of major Chinese manufacturers interviewed for this study indicated that CDB finance for foreign projects is subject to lengthy approval procedures. The CDB is also more risk averse in foreign markets, where it has less prior knowledge on renewable energy projects' finance and profitability, and less certainty of continued government support for wind power projects when compared with the domestic market.

Lastly, manufacturers may invest themselves, or acquire finance from Chinese utilities that seek global expansion. Sany financed wind farms in the US and Tianrun, Goldwind's subsidiary, financed wind farms in the US and Australia. Longyuan and Datang have global expansion plans as well, which may improve export chances for United Power, XEMC and China Creative (see connections in Table 6). This will depend on turbine performance, however. In global markets, these utilities are not driven to invest by renewable portfolio standards, and will invest only if projects are profitable. Both Longyuan and Datang have recently signed MoU with Gamesa for projects outside of China. As such, it is unclear whether relationships with preferred suppliers in the Chinese market will hold up in global expansion projects. As the bulk of these projects is still being negotiated, it is too soon to comment on this with much certainty, however.

4.7. Creation of legitimacy

Government support for wind power utilization in China largely stemmed from the necessity to meet fast increasing power demand, whilst reducing emissions of environmentally harmful substances. Chinese policy support for the wind power equipment industry has long focused on the need to reduce dependency on foreign technology and manufacture. The use of manufacture from domestic industries would reduce costs associated with wind power utilization targets and create new economic activity. To achieve this, (earlier) policies supported technology transfer and domestic procurement (for a historical overview of policy developments, see e.g.,Lewis, 2007; Ru et al., 2012).

Recent policies have been more confident about the capabilities of the domestic turbine industry, and ambitions now include expansion into global markets (see Table 1). Amongst others, finance made available via the China Development Bank should help achieve such targets. Support for domestic developments and global expansion differ, in that it is driven by industrial rather than environmental policy. There are, for instance, no Chinese policy targets or power price subsidies for utilization of wind power outside of China. Whilst it is accepted that utilization of wind power within China will require financial support, expansion into global markets ought to increase industrial and tax revenue. Such projects, therefore, have to be profitable in order to be implemented. The Chinese government, via The CDB, may cover investment risk but will not subsidize projects.

5. Synopsis

China’s contribution to the global wind power sector is undeniable. Annual installations in China are larger than anywhere else in the world. This large domestic market has spurred the establishment and growth of domestic manufacturers; a number of which are now amongst the world’s largest.

The domestic market is highly competitive, with very demanding customers, or what Fagerberg would call ‘advanced domestic users’. The competitive pressure created by these customers is strongly targeted towards lower turbine cost. The more comprehensive ‘levelised cost of electricity’, which includes consideration for turbine efficiency and maintenance needs, is of secondary concern. As such, demands from customers in China differ from what is expected in most export markets. The recent trend towards integration between wind farm developers and turbine manufacturers may reduce the competitive pressure on selected manufacturers for technological improvement.

With little or no public data on turbine performance, it is difficult to accurately assess quality differences between turbines from Chinese manufacturers and global leaders. However, the presidents of Sinovel and Goldwind themselves assessed there to be a “quality gap with international leaders” or even “far behind on Vestas, GE or Siemens” (CWP 2012 conference, 2012). Although many manufacturers have independently developed their latest turbine models, the number of patent grants to Chinese manufacturers remains relatively low. This further indicates technological development strength remains moderate when compared with global leaders and casts doubts on the vintage of technology embedded in those latest turbine models. For now, China’s leading appearance in statistics on installed capacity and manufacturers by output volume should be understood to be due the existence of a favourable and very separate environment in the domestic market. These statistics should not immediately be considered as indicative of global leadership in innovation.

Fagerberg’s conclusion that technological leadership is a precondition for the development of export markets may, however, be challenged by the fact that markets for wind turbines are not perfectly commodified. Sales of turbines are always tied up with project finance. Although Chinese turbines will face difficulties in passing due diligence of foreign project developers, finance may be available from the manufacturer’s own balance sheet, the China Development Bank, or Chinese utilities that seek global expansion.

It should be noted that Chinese policies have been highly effective in creating a domestic industry for wind turbines. The separate nature of the Chinese and global markets have essentially created a nursing or niche market for the domestic industry. It is likely that perfectly open competition with foreign competitors would not have yielded the same results, because of the late-comer nature of the Chinese turbine industry.

Domestic turbine manufacture has by now developed into a veritable industry, and policies should be adjusted accordingly. Further advances towards global technological leadership would require the Chinese policy and market environment to be more in line with global demands. A more rewarding environment for high quality turbines would require improvement of grid connectivity and curtailment, as well as more openly competitive equipment tenders with less focus on turbine cost.

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Regime dynamics and the rise and fall of a solar photovoltaic industry in Norway – system building and knowledge flows

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1 Introduction

This paper aims to analyse the role of context in processes of system building for renewable energy technology (RET) and addresses how a technological innovation system interacts and draws on its context. The overall question dealt with is how existing technologies, knowledge bases and actors impact on the development of new technologies, and the innovation systems in which they are embedded. It thus is a question of how existing regimes – the mainstream of knowledge development coupled to a technological trajectory – impacts on the development and diffusion of novelties during processes of system building.

This paper analyses the case of solar photovoltaics (PV) in Norway and illustrates how an existing regime impacts on processes of system building. The paper asks *what is the role of existing regimes for energy transition in Norway and how can regime change and formation of new technological innovation systems come about through exploration and exploitation of diverse systemic contexts?*

The paper argues that system building for solar PV in Norway relied on: (i) well-established industrial actors linked to the existing chemical processing regime which (ii) pursued long-term learning processes associated with silicon production as well as diversification efforts which (iii) enabled knowledge flows linked to networks that (v) combined with existing knowledge bases, infrastructures and resources enabled a diversification into solar PV. The paper has a twofold purpose. First to analyse dynamics linked to an existing regime, and use the case of solar PV in Norway to illustrate opportunities and challenges with how bottom-up processes of change (bottom-up here understood as absence of deep public sector top-down involvement in transformation processes). The second purpose is to analyse the nature of such bottom-up driven change given that the case of PV in Norway seems to differ from other cases where system formation depended on co-evolution of policy and industry formation (see Jacobsson & Lauber 2006 for analysis of the role of institutional change in energy transition in Germany). This case sheds light on system formation processes in the absence of national deployment programs and indeed top-down oriented transition strategy. However, like the PV industry in the rest of the world, the industry in Norway experienced a dramatic downturn in recent years, with many firms reducing their activities. This indicates challenges and problems associated with pursuing this type of development path over time. A second question dealt with here is therefore linked to how bottom up transformation in the absence of deeper public sector involvement pans out in a context of international competition.

The paper is structured as follows. I first present an analytical framework that draws on perspectives dealing with energy transition and building of new innovation system and focuses on a discussion of how we can discuss dynamics linked to existing regimes and how it impacts on system building. Secondly I describe the evolution of a TIS for solar PV in Norway, followed by an analysis that first deals with path dependence and regime dynamics and the process of system building and knowledge flows. Conclusions are given in the final section.

1.1 A brief note on methods

This paper takes a case study approach in order do build explanations with regards to how a PV TIS emerged in Norway. It mainly draws on interviews with key stakeholders. Interviews were performed in 2011/2012 with actors directly (firms along the value chain and suppliers) or indirectly (public authorities) linked to PV. Most interviews were made with firm representatives both at CEO or technical management level. I also draw on some secondary sources for contextual and historical background for the study.

2 Analytical framework

The purpose of this section is to line out a framework for the analysis of emergence of new technologies in the context of energy transition with a focus on the dynamics linked to prevailing regimes. I am drawing on two well-established frameworks that discuss transitions and the emergence of new technologies. Both the TIS framework (Johnson & Jacobsson 2001, Bergek et al 2008, Hekkert et al 2007, Markard & Truffer 2008) and the multi-level perspective (MLP) (Geels 2002, Geels & Schot 2007, Smith et al 2005) discuss the role of existing industries and sectors in processes of energy transition. In the TIS framework external inducing and blocking mechanisms refer to contextual determinants that can enable (or block) formation of a new system, which in its emerging phase is argued to depend on a broader context for structural and functional dynamics (Bergek et al 2008). Analysis of impact of broader regime and sectoral systems on TIS formation and dynamics is however a somewhat neglected issue in the TIS framework. Although the MLP emphasises the notion of a socio-technical regime as a stable meso-level that constrains opportunity for (radical) change, recent modifications (Geels & Schot 2007, Smith et al 2005) also address regime level transformation. The notion of regime dynamics does however open up questions of what characterises regime search and learning processes and indeed how new knowledge enters an incumbent regime. In terms of regime dynamics and the MLP there exists a challenge in terms of conceptualising an agency perspective that can encompass how actors, networks and institutions are linked to the dynamics coupled to a prevailing regime.

2.1 Regime dynamics and niches: challenges of conceptualising emergence and improvement of novelty

2.1.1 Transitions and the role of what exists

The concept of a regime lies at the heart of many of the approaches dealing with transition (Geels 2002, Kemp et al 1998, Markard & Truffer 2008) and has a range of antecedents. Within the innovation literature the first notions of technological regimes (Nelson & Winter 1982) and technological paradigms (an adaptation of Kuhn's concept of paradigm shifts in science) (Dosi 1982) described how practices, routines and cognitive frameworks guide search and problem-solving activities, primarily amongst engineers. This implies that what exists impacts on what potential new knowledge development that is possible. Change, in other words, is path dependent.

The literature on technological transitions broadened the concept to include user aspects and societal issues. In fact the approach is oriented towards analysis of how scientific and engineering practices are embedded in social contexts were these become intertwined with users, institutions and infrastructures (Kemp et al 1998 Geels (2002) proposed the concept socio-technical regime to accentuate this distinction and to argue that not only scientists and engineers, but also policy makers, business investors, end users and social interest groups etc. share rules and practices that constitute a regime.

In this paper I apply the concept of a regime to depict complexity and structuredness of technology and thus its associated potential change. Smith (2000a) defines a technological regime as:

> "… the overall complex of scientific knowledges, engineering practices, production process technologies, product characteristics, skills and procedures, institutions and infrastructure which make up the totality of a technology (p. 92)."

The concept of a technological regime therefore articulates what technology is. Just as the concept of a socio-technical system, it reflects how technologies do not exist as single artefacts, but rather as interlinked multiple structural elements including the elements described above. In other words technologies are embedded in wider social and economic contexts characterized by their associated knowledge bases, practices and skills and therefore by certain ways of doing things. The notion of a technological regime reflects these dimensions of complexity and stability.

Regimes are seen to provide barriers to (radical) change because they stabilise technological trajectories. Change must conform to the "rules" of the regime, and this constrains the development path of a regime - it is path dependent (David 1985, Nelson & Winter 1982, Unruh 2002). There is therefore a limited scope for change at any point in time. A regime thus represents a selection environment that through its temporal and structural stability represents a barrier to novelty and hence also determines how technological trajectories evolve. In other words the technological trajectory - the evolutionary path - of a regime evolves depending on knowledge, institutions and technologies already existing and ordered in a regime (see also Lundvall 1992, Carlsson & Jacobsson 1997, Johnson & Jacobsson 2001 and Unruh 2000 for arguments on this). Innovation, change and search characteristics related to technologies embedded in a regime hence are determined by the regime itself.

In sum the regime concept depicts broad, socially embedded, barriers to (radical) change and reflects the stabilising forces of that what already exists. The core idea is that it inhabits a set of logics and rules for incremental change along an established trajectory. Regimes are problematic in a transition perspective not only because they stabilise a production and consumption pattern that may be unsustainable but also because they constrain emergence of new technologies because these do not match the existing regime. In an energy transition perspective technologies in the energy system are part of a regime governed by actors, institutions and infrastructure, which has been allowed long-term learning and development processes.

The challenge then is understanding how we can conceptualise change and how transition technologies emerge and improve against this background. In the following section I discuss how we can understand the emergence of new technologies against the face of existing regimes – i.e. how the new can emerge in the context of what already exists.

2.1.2 Change, regimes and niches

In pursuit of developing an analytical perspective that deals with how change can come about on the basis of existing regimes I take as a starting point a prominent perspective in the transitions literature; the multi-level perspective (MLP) (Geels 2002, 2007 Berkhout et al 2004, Smith et al 2005). In attempting to conceptualise change in relation to the regime concept, this approach attempts to create a broad perspective of change and transition. The perspective is oriented towards explaining transition dynamics by the interplay of processes at a three level conceptual framework consisting of niche-innovations, socio-technical-regimes and landscapes[1].

Change in the MLP originally is seen to take place through interaction between these three levels. Novelty is assumed to emerge in niches, which are conceptualised as the context within which new technologies are protected from the mainstream market (Geels & Schot 2007).

In the classic MLP perspective (proposed in Geels 2002) niches are thought to penetrate regimes if they are allowed to increase price/performance ratios through learning processes, often aided by support from powerful groups (Geels & Schot 2007). In the (early) MLP perspectives, change was thought to come about through niche-innovations building up internal momentum by processes of niche accumulation (a broadening and diversification in user or application contexts (Geels 2002). This momentum is argued to be in need of support from landscape pressure bearing upon the regime, as well as destabilisation of the regime, which creates opportunities for niche penetration. Niches thus are seen form, grow or decline in interaction within regimes and landscapes (Geels & Raven 2006).

Firstly it is important underline that the concept of a niche bears connotations towards a user side. If we distinguish between the protection and generation of technologies, bluntly speaking, the first has user connotations whilst the latter also involves a "producer

[1] The macro level in the MLP is referred to as the *socio-technical landscape*. It refers to a broad exogenous social and cultural environment out of influence of niche and regime actors. Development on macro-economic and macro-political levels is thought to constitute this level. Landscape level dynamics (Geels 2002) slowly change over time, and exert pressures on regimes. Such pressures hence may be associated with significant time lags if such pressures are in fact absorbed in regime levels.

dimension". Thus, while it is comprehensible to think about niches as providing shelter from competition on the mainstream market it is less obvious how technology generation takes place at this level, that is outside of the major current of technological trajectories evolving on regime levels. A major question therefore concerns what constitutes the generation of new technologies within the niche context, and how it differs from dynamics on the regime level in terms of production and supply of technologies.

Georghiou et al (1986) and Rosenberg (1976) make the point that niches and technology users are fundamental to improvement processes by impacting on innovation processes. The main point which I am making here however is that the MLP leaves us with questions of which processes are associated with the emergence of technologies in terms of the supplier (producer) side and their dynamics linked to users and niches. In other words, agency on the behalf of those linked to the production, supply and improvement of technologies, can be argued to be underplayed in the MLP.

2.1.3 Regime dynamics

The MLP has received criticism for being too niche focused and bottom-up biased (Berkhout et al 2004). The criticism mainly was oriented towards the understanding of change only emerging through the niche level. This point of criticism is important with regards to the locus of analysis in this paper given the aim of exploring the dynamics associated with endogenous regime, i.e. dynamics occurring on the regime level and not necessarily on the niche level.

Responding to the criticism of a presumed niche-driven bias Smith et al (2005) and Geels & Schot (2007) broadened the MLP perspective to include different paths of change, including change coming about on behalf of activities by regime actors.

As a basis for the more nuanced discussion of interaction amongst the three levels of the MLP, Geels & Schot (2007) add two criteria to distinguish between different pathways; (a) the timing of interactions and (b) the nature of interactions. The first refers to how changes on the different levels (niche, regime and landscape) are timed in relation to each other. For instance if "…landscape pressures occur at a time when niche-innovations are not fully developed, the transition path will be different than when they are fully developed" (Geels & Schot 2007, p. 405). It is important to notice how novelties or niche-innovations are treated in this perspective. In particular how innovation can be categorised along an axis of development (i.e. fully-developed or not). This distinction may be equalled to the critical dimension of post-introduction improvement that relates to how technologies usually are crude at their introduction and usually are improved massively over time (Rosenberg 1976, Georghiou et al 1986). This point is made explicit by Kline & Rosenberg (1986) who argue that:

> The fact is that most innovations go through rather drastic changes over their lifetime – changes that may, and often do, totally transform their economic significance. The subsequent improvements in an invention after its first introduction may be vastly more important, economically, than the initial availability of the invention in its original form (Kline & Rosenberg (1986): p. 283).

Out of such a perspective the label of fully-developed does however not resonate well with the notion of continuous change, which is the critical factor constituting change along the line of improvement.

Furthermore this paper is dealing with the conceptualisation of endogenous regime change. Geels & Schot (2007) propose one transition path of particular relevance - the *transformation path.* This path is argued to occur in situations where niche-innovations are not sufficiently developed and there is moderate landscape pressure. In such cases regime actors will respond by modifying the direction of development paths. The Geels & Schot (2007) and Smith et al (2005) perspectives of endogenous transformation paths hence is an exception in the transitions literature with regards to conceptualising regime actors as agents of change.

The perspectives on the role of existing regimes for bringing about dynamic change is however briefly treated, and does not for instance discuss how new knowledge enters the regime and what the role of cumulative adjustments and reorientation has for the emergence of technologies, i.e. novelties which may enable overall transition processes. Beyond the idea of niche penetration, which can be read as representing mainly a new application context, innovation dynamics and indeed the interplay with diffusion is not highlighted to any extent. Thus, an improvement perspective including the dimension of technology producers does not attain a pivotal place in the framework. The perspective also lacks a conceptualisation which types of processes and structural dynamics (for instance in terms of intra-regime search and learning processes) that are taking place during endogenous transformations. Although the MLP makes important points regarding the role of new user groups (niches) supplier side groups receive less attention (from an technology improvement perspective we could add the responses by supplier side groups to user side demands). Indeed a systemic linking between these key actor groups is not emphasised. Therefore it may be argued these perspectives do treat innovation processes within the regime fairly lightly.

This conceptualisation of regime change thus leaves us with questions related to which types of processes and mechanisms that are at play in regime change. How can a regime (understood as a stable meso-level configuration) be a locus of change and how we can discuss what exists also as a basis for change, innovation processes and processes of technology improvement? If we acknowledge that regime change can be endogenous, then the question of which mechanisms for new knowledge to enter the regime becomes relevant. Moreover, what is the nature of search and learning processes taking place within the regime in order to facilitate change along more disruptive and radical dimensions? It is these innovation processes associated with change in existing regimes and emergence of new TISs that I am preoccupied with in this paper.

2.1.4 Path dependence

Underlying the concept of a technological regime lays an idea of stability, and change along ordered trajectories. Evolutionary thinking on technological change argues that such processes are cumulative and path dependent. What does this concept entail, and to what extent are perspectives on path dependence purely used as to conceptualise and depict constraint and inertia (i.e. a perspective taken to argue that regimes are antagonistic towards novelty)?

A common perception of path dependence resonates with the general and intuitively graspable idea that "history matters". An initial open definition of path dependence may be as follows; "...what is done in the future is determined by what is learned in the past" (Pavitt 2005) or "A dynamical process whose evolution is governed by its own history is path dependent" (David 2007). Path dependence is therefore a concept that reflects historical contingency. Change hence does not emerge in vacuums but rather evolves out of what exists. And it is precisely what exists which defines what is "searched for" and what aligns with an existing regime.

Limiting the understanding of path dependence to simply viewing processes as historically contingent does not in itself explain much of how processes of change take place, nor in which ways history may matter. In the literature on path dependence, attempts have been made to further define and clarify the concept in a range of differing approaches. In the works of Paul David (1985, 2000, 2007) the notion of path dependence is recurring, to discuss *how* processes of change are historically contingent. Much of this work revolves around identifying mechanisms underlying path dependent processes, such as applying the concepts of "quasi-irreversibility" and "non-ergodicity" (David 1985, Arthur 1989, 1994). The latter refers to a process, which is influenced by random events at previous points in time, causing the outcomes of processes to be affected by their own history. Hence, if a process is non-ergodic initial conditions influence the outcome. This notion also resonates with David's (1985) references to "quasi-irreversibility" where process irreversibilities arise not only at the outset of a process but also from events occurring on the path. To describe irreversibility David (2007) uses the analogy of a "fork in the road", where choices made to follow a certain path are made due to repercussions of choices made in the past.

Path dependence therefore also is a continuous mechanism, just as innovation. Strengthening of a technological trajectory may take place continuously. Path dependence hence is tightly linked to diffusion because improvements in a technology during its diffusion process embed technology more broadly in society, and hence contributes to bigger barriers to change a path. If we think of regimes as path dependent the continuous accumulation of knowledge and improvement of technology strengthens the regime. Old technologies may therefore have advantage over new ones given that they have experienced learning and development within a technological trajectory.

A critique issued against strong proponents of path dependence revolves around the degree of "manoeuvring space" within paths (i.e. the possibility and ability to create novelty). Garud & Karnøe (2001) proposed the idea of path creation as a critique of the notion of "historical accidents" guiding creation of novelty. Acknowledging the constraints of path dependence but arguing that this also entails "mindfully deviating" from such structures (p. Xii). This in turn relates to the room for creativity within paths.

If we are interested in the emergence and diffusion of innovation the notion of path dependence becomes interesting if it can tell us something about how history matters in the context of emerging novelties. Antonelli (2006) suggests that creativity and reactivity also is present within existing paths, arguing that "history matters all the time" (p. 62), not only at the outset of a process. Antonelli`s (2006) conceptualisation of path dependence refers to a process in the borderland between a historically deterministic process where its outcome is purely defined at its outset conditions and a historically dynamic where "...one accident follows another relentlessly and unpredictably" (p. 54). A path then is constituted by a technological learning trajectory that also has open-ended future possibilities. These are guided by continuous additions of new knowledge that in turn may constitute learning trajectories to shift. The inclusion of agency, present in the works of Garud & Karnøe (2001) and Antonelli (2006), does then open up for the idea of continuously shifting possibilities for generation of novelty.

The inclusion of an agency perspective is important out of an evolutionary perspective were selection outcomes can be multiple. Path dependence, in an evolutionary perspective where change may have numerous outcomes, thus also works as a focusing mechanism of a technological paradigm or regime: “In short, a technology paradigm is a device for dealing with the tyranny of combinatorial explosion (Metcalfe 1995, p. 35).” A technological regime or paradigm thus is also a way to organize the world and can give direction to learning and search processes. Change in turn is path dependent due to the regime “controlled” evolution of technological trajectories. But, as argued by Garud & Karnøe (2001) this can also enable modifications and shifts in trajectories.

So, given that there is room for reactivity in existing trajectories, how can we analyse these processes of change in terms of agency and actors? The following section proposes to use the technological innovation systems approach to shed light on how actors, networks and institutions ”work with” and are linked to existing trajectories or regimes.

2.2 Technological innovation systems – a knowledge flow perspective on system building

Having opened up the possibility of endogenous regime change in conceptual terms, the challenge of empirical analysis of such phenomena remains. Indeed it opens up questions related to which types of processes and mechanisms that are associated with change at this level, as well as in defining an agency perspective.

The perspective of technological innovation systems (TIS) (Johnson & Jacobsson 2001, Bergek et al 2008, Hekkert et al 2007, Jacobsson 2011) provides fruitful insights on how systems evolve to become capable of generating and diffusing technologies. Out of this perspective the emergence and improvement of technology can be conceptualised and analysed as a process of system building. The process of system building is one associated with including firms, knowledge organisations, finance actors, institutions and public authorities, amongst others, in the generation and diffusion of technology (Johnson & Jacobsson 2001, Carlsson and Stankiewicz 1991). The TIS approach has made important steps forward when it comes to providing a coherent and more dynamic and process oriented framework for analysis of the dynamic evolution of specific technologies, which in fact are quite complex. Proposing an addition to structural analysis inherent in traditional systems approaches, the TIS approach puts focus on *processes* (referred to as functions) in addition to structural analysis, by applying a functional approach (Bergek & Jacobsson 2001, Bergek et al 2008, Jacobsson 2008, Jacobsson 2011 Hekkert et al 2007). These approaches look not just at the structure of a system but at its functionality, what it actually does and achieves. This perspective and its associated processes is used for the analysis of strengths and weaknesses in the system building process for solar PV in Norway in section 5. The individual processes are described here.

While I use the concept of a technological regime to depict the complexities of a technology in terms of its knowledge bases, skills and routines (Smith 2000a), I apply the TIS perspective to discuss agency related to a regime, i.e. how actors, networks and institutions can develop, maintain or change a regime. In other words a TIS, and its associated actors, networks and institutions are here viewed to "work with" the structured technology that can be viewed as a regime.

In order to include an agency perspective to the analysis I use the TIS perspective to discuss how the old impacts on the new. i.e. how a new TIS is formed within an existing context. A guiding question which I am dealing with in this section is how new systems can be formed on the basis of an existing context. A key hypothesis given the perspectives on path dependence and regimes discussed above is that knowledge, actors and other system components must "come from somewhere".

This section aims to bring the question down to a more analytically surmountable level by introducing the dimension of *knowledge flows* to the discussion of delimitation of system boundaries and interaction amongst systemic contexts in system building.

This takes us back to one of the key messages of the systemic framework which highlights not only the pivotal role of competition amongst firms, but also stresses how formal and informal collaboration patterns are intrinsic to innovation processes. These interactive forms of learning are at the core of systems perspectives, and the reason for such interaction is often that problem-solving activities depend on knowledge outside of existing firm capabilities (Smith 2000b, Smith & Robertson 2008). When firms wish to do something new their existing capabilities often are insufficient, which creates the need to search for and absorb new knowledge outside of the boundaries of the firm (Cohen & Levinthal 1990). Knowledge flows amongst firms and other organizations hence constitute an important means for learning across organizations that may enable and strengthen innovation processes.

Out of TIS perspective a relevant question would be whether the same type of phenomenon holds for the system level as well? Is the knowledge base of a TIS sufficient to facilitate emergence and sustain growth on its own, or does emergence and growth depend on other systemic contexts? If so, what is the nature of such inter-systemic dynamics and how can we talk about them in terms of knowledge flows? These questions relate intimately to two central issues when applying the TIS approach, namely how (i) TISs are dynamic and evolutionary in nature and (ii) how TISs are defined along boundaries of specific technologies and knowledge fields.

(i) The dynamic and evolutionary perspective of TIS hence is one dealing with questions of how systems emerge and grow, and one thus cannot expect forming TISs to be fully developed and therefore drawing on other systemic contexts: "In emerging TIS, few specialised components can be expected to exist and the structural overlap with – and dependence on – other systems is, therefore, likely to be particularly large (Bergek, Jacobsson & Sanden 2008, p. 576)". The notion of dependence of other systemic context during formation of a TIS therefore is related to how knowledge (as well as other structural and functional characteristics) exogenous to a TIS may be important for emergence of internal dynamics. In other words actors, networks (and their associated knowledge bases) distributed across sectors and industries can be assumed to influence the dynamics of a particular TIS.

(ii) This leads us to the second point. We can envisage TISs and their associated actors, networks and institutions to be delineated along boundaries of specific technological or knowledge fields, at the same time as existing within broader contexts in both horizontal and vertical dimensions. A TIS therefore is not only shaped by neighbouring TISs but also along regional, national and sectoral dimensions (SIS). In fact a TIS may span across a range of countries and several sectors (Markard & Truffer 2008). Therefore, structures in neighbouring TISs, higher aggregate system levels such as related industries (Porter 1990) and sectors (such as, for RETs, the electricity sector) or in national policy frameworks can play a role in the formation of a TIS. Boundaries of a TIS are viewed as fluid and the process of system growth amongst others includes the incorporation of new knowledge from other systemic contexts (Bergek et al 2008).

We may argue that even though the TIS framework aims to "…handle an integration of technology specific and more general influencing factors" (Jacobsson & Bergek 2011: p. 53) the issue of context and how it affects system formation, growth and performance still is under-investigated. A critical aspect is for instance related to the question of where an emerging TIS gets its actors. Moreover, if TISs draw on various systemic contexts how can we discuss this in analytical terms?

This in turn leads us to the question of what constitutes such overlaps and indeed how we can understand what can be labelled inter-systemic interaction, i.e. what constitutes the dynamics among actors and networks embedded in (and linking) different systemic contexts, and how can we link this to our understanding of system building processes?

2.2.1 Knowledge flows

The issue of inter-systemic knowledge flows links up with the perspectives technology improvement in an intrinsic sense because empirical evidence shedding light on the developments needed for technologies to become more viable are associated with how "…ancillary inventions or improvements, frequently from other industries, are needed." (Mowery & Rosenberg 1998: p. 3). Similarly the literature on sectoral innovation systems stresses that although knowledge bases differ across sectors, they also are characterised by complementarities and interdependencies with important impact on system dynamics (Malerba 2002).

Moreover, given that knowledge bases differ across sectors, and that the basic underlying perspective underlying evolutionary perspectives is innovation and new technologies as new combinations of existing knowledge, components and principles, inter-systemic flows of knowledge may be argued to play pivotal roles for how new technologies emerge. This rests on the classic observation that key technologies and innovations are important across industries (Mowery & Rosenberg 1998). There exist abundant examples of this through history, which amongst other describe how jet engines became fundamental to development of natural gas power plants or how ball-bearings for bicycles became important for the development of cars (Nemet & Johnson 2011). Although Nemet & Johnson (2011) do not find a similar pattern through patent analysis, the cases illustrated by Mowery & Rosenberg (1998) and Smith & Robertson (2008) do indicate that the qualitative of innovation processes are defined in part by important linkages between technologies and industries, which involves knowledge flows.

In order to operationalize the idea of inter-systemic dependence in processes of system building I draw on the notion of knowledge flows. Smith & Robertson (2008) propose that distributed knowledge bases play a core role in many industries given that the "…relevant knowledge base for many industries is not internal to the industry, but is distributed across a range of technologies, actors and industries (Smith & Robertson 2008, p. 86)". Inherent in this proposition is that the flow of knowledge between actors, industries and sectors is vital for innovation, due to the need to combine knowledge bases with origins in different contexts and industries.

Knowledge flows may therefore be identified at inter-organizational, inter-industry and even inter-systemic levels. These may appear in both embodied and dis-embodied forms (Smith 2000b). Embodied knowledge flows may be identified in cases where technologies are applied across sectors. General purpose technologies such as ICTs or biotechnology are examples of how technologies become inputs to other sectors giving rise to new types of dynamics and increase of performance. Pol et al (2002) propose a sector typology consisting of enabling and recipient sectors in the dynamics of efficiency enhancing products within and between sectors. The role of technology flows, including embodied knowledge flows, hence may play an important role in creating dynamics in systems external to those where technologies are originally developed or applied.

Disembodied knowledge also may play a critical role across industries and systems and has to do with flows of knowledge from a wide range of background knowledge bases. ICT development for instance relies on the developments within the electronics industry and its related knowledge field such as solid state physics, as is the case with solar cells (Goetzberger & Hoffmann 2005). The various sets of knowledge that go into the development of new products or processes hence have multiple inputs, and the knowledge flows which facilitate such dynamics have origins in a range of systems. A disembodied flow implies knowledge not embedded in "hardware", and often has tacit characteristics. Such flows may for instance take place in interaction amongst actors and networks. Embodied and disembodied flows may in turn be comprised by a set of sub-categories:

Knowledge flows	
Embodied	***Disembodied***
Equipment	*Consultancy*
Materials	*Education*
Components	*Personnel*
Machinery	*Scientific literature*

Table 1: Knowledge flows (Adapted from Smith 2000b).

2.3 Existing perspectives on innovation and system building for solar PV

The purpose of this paper is to analyse a process of system building for solar PV in Norway. Studies that focus on system building for PV often empirically analyse in depth dynamics embedded in specific countries, i.e. technological innovation systems embedded in a national context. Jacobsson et al (2004) and Jacobsson & Lauber (2006) for instance analyse system formation process for PV in Germany, and stress the importance of institutional change. Jacobsson et al (2004) for instance show how an initial phase associated with federal R&D support was supplemented by larger institutional change leading to a broader formation of markets that speeded up the system building process. Jacobsson & Lauber (2006) discuss underlying dimensions of institutional change and illustrate the role of strong coalitions in the political struggle to achieve change.

Successful system building therefore seemingly is reliant on co-evolution of push and pull mechanisms usually involving a strong government strategy and deeper public sector involvement. Kimura & Suzuki (2006) make a similar point with regards to the emergence of solar PV in Japan. A set of broad legitimising factors also seem to be playing a critical role, and are related to energy security amongst others. Both in Germany and Japan solar energy initiatives were strengthened in the aftermath of the 1970s oil crises (Jacobsson et al 2004, Kimura & Suzuki 2006). In these instances key national policy objectives such as energy security seemed to play critical roles in forming foundations for more broad scale institutional change paving the way for deployment programmes often going hand in hand with technology push policies, such as massive R&D investments.

In a similar vein, although illustrating challenges with system building, Negro et al (2008a) discuss how the system formation process for solar PV in the Netherlands was challenged by instability and high fluctuations in public policy related areas such as market formation. Together these studies show how system-building processes differ processes across countries, and therefore legitimate the analysis of system building processes in Norway.

Klitkou & Coenen (2013) apply a regional innovation system perspective to the analysis of the emergence of a PV industry in Norway to display differences in spatial patterns. This study highlights how various regions have played different roles during the formation of a national PV industry. Lines may be drawn between urban and more peripheral regions, where the Oslo region is argued to be an important driver for development in Eastern, Southern and Northern Norway. Hanson (2008) discusses industry formation in Norway up until 2006. These studies did however not explicate a TIS perspective and a discussion PV emergence as a bottom up driven process and of the role of incumbent regimes and actors in facilitating knowledge flows. Hanson (2011) also provides an analysis of PV in Norway, but focuses on new processes developed by silicon producers. The remainder of this paper analyses a system formation process for PV in Norway, and focuses on the role of the incumbent industry on the one hand, and the importance of cross-systemic knowledge flows on the other.

Having outlined a framework for analysis of endogenous regime change and the role of contexts for energy transition the following section presents the emergence of a Norwegian solar PV TIS in a four-phase development. This is followed by an analytical discussion highlighting the role of path dependence in diversification processes and its reliance on inter-systemic dynamics and knowledge flows in the process of system building.

3 The formation of a technological innovation system for solar photovoltaics in Norway – a four phase development

In this section I describe the rise and fall of a technological innovation system for solar photovoltaics[2] in Norway as a four phase process consisting of; (a) a pre-production phase characterised by production of lower grade metallurgical silicon (b) a formation phase marked by the emergence of the first industrial ventures in production of silicon wafers for solar cells, (c) an expansion phase marked by an increase in organisations and firm size as well as stronger activities in upstream activities and (d) a downturn phase characterized by reduction of solar PV related activities in Norway.

By and large the story is about how organisations and entrepreneurs with origins in the traditional ferrous metals industry ventured into solar PV, which subsequently resulted in the formation of a PV TIS in Norway. Dynamic interaction with external system contexts both spatially and in terms of linked knowledge fields were important. A range of countries including Germany, Japan and the US in particular had established substantial research traditions, industrial development and even markets before Norwegian actors entered (Bradford 2006, Jacobsson et al 2004, Kimura & Suzuki 2006). The story is however not one of imitation. Long term learning processes, incremental innovation resulting in production and cost reduction resulted in formation of Norwegian solar PV technological innovation system, which did have a competitive advantage as well as characteristics which stood out in a global comparison, mainly due to its upstream orientation. However the crisis and downturn in the global PV industry also was felt in Norway. As a result the structural and functional

[2] The photovoltaic effect allows the conversion of solar radiation to electricity by the means of a semiconducting material (most commonly silicon) (Goetzberger et al 2003). In the production of PV technology we may distinguish between (i) raw-material production (silicon (with high purity) is dominant) (ii) crystallisation and production of ingots (blocks of silicon) (iii) cutting of wafers (iv) cell production and (v) module production. The need for high purity materials relates to the ability to absorb photons. The industry supplying solar cells and modules is commonly referred to as the photovoltaic (PV) industry.

dynamics of the system changed quite rapidly over the course of a few years. The overall issue discussed in the following section is the dynamics and nature of a bottom-up systemic formation process in dependence of knowledge flows and inter-systemic dynamics.

3.1 Pre-production phase (1980-1994)

The history of solar PV in Norway starts decades before there existed any actual production. In fact we may trace important knowledge, structural and institutional dimensions back at least half a century. Two co-evolving processes were of particular importance in this phase; (a) continuous development of core competencies within metallurgical knowledge bases related to silicon production and (b) explorative activities in relation to new technologies and markets.

Metals, minerals and natural resource based process technologies were central in Norwegian industrial development throughout the 1900s (Wicken 2009). Many of these industries were highly energy intensive and the vast potentials of hydropower for electricity generation made rapid industrial expansion possible (Wicken 2011). Ferrous metals and silicon became part of key export industries related to natural resources throughout the century. On the other hand the process industry, including production of ferrous silicon is a large emitter of climate gasses (SSB 2013b). This industrial sector has also been associated with path dependence and lock-in, and has been argued to be little prone to change (Narula 2002). In other words the ferro-alloy industry can be linked to an existing regime associated with challenges in terms of emissions.

Traditionally Norwegian firms in silicon production were preoccupied with production of lower-grade purity metallurgical silicon[3] (MG-Si) and for a long period of time were one of the world's largest suppliers in this market segment (Ceccaroli & Lohne 2003, Enger 2011). A range of companies had production facilities in Norway, including FeSil, Finnfjord and the largest producer; Elkem, which also was the world`s largest producer.

Ferrous metals were part of Elkem`s larger portfolio of process technologies, of which they had developed strong know-how, for instance with regards to melting furnaces, refining of metals and silicon production. The Søderberg electrode, which radically changed electro-

[3] Metallurgical silicon is for instance used as an aluminium-silicon and in the silicone industry (Wærnes et al 2006). It is also used as a raw material in the production of higher purity silicon. Electronical grade silicon is mainly used in the semiconductor and electronic industry and is often referred to as polysilicon (Goetzberger et al 2003). This type of silicon is also traditionally the raw material used in the photovoltaic industry (Woditsch & Koch 2002).

chemical processing (including aluminium (Moen 2009)) in its time was developed at Elkem (Sogner 2003). This critical innovation enabled major exports and was widely adopted. Elkem not only functioned as an export firm but also as an entrepreneurial hub and a range of spin-off firms were established (Wicken 2009).

3.1.1 Searching for higher value added activities

Although sticking to production of lower-grade silicon Elkem maintained on-going search and knowledge development activities. These were linked to experimentation with new forms of processes for production of higher grades of purity, and lower production costs. New market segments did emerge, particularly those associated with growth of the electronics industry. At the same time Elkem`s metallurgical silicon activities were associated with low value added (Tronstad 2011). Estimates indicate that value can be multiplied by a factor of 30-50 by moving from metallurgical to electronical grade silicon (Ceccaroli & Lohne 2011). Key to Elkem`s strategy over time was entering new markets by means of cost efficient processes (Tronstad 2011). An important step in this process was the introduction of custom purity “Silgrain”. The relatively high purity levels of “Silgrain” gave particularly good results for polysilicon producers who were the main customer group (Sogner 2003, Ceccaroli & Pizzini 2012).

The search for new and cost efficient processes and new market segments was enabled by firms such as Elkem that had long time horizons in their development strategies, at the same time as there grew forth a collaborative environment between key actors in the industry (Tronstad 2011). The establishment of the “The Norwegian ferroalloy producers research association[4]” (FFF) is an example of the latter. This is an associated founded by industry actors in the ferroalloy industry with the goal of pursuing joint research (FFF 2013).

A core element in silicon production is the melting furnace. Knowledge at Elkem to a large extent had evolved around experimental learning by doing (Sogner 2003). A need for scientific understanding and knowledge gradually became evident as new processes were sought to be developed. In particular demand for systematic mapping of what actually went on inside melting furnaces was of importance. This lead to the integration of various forms of scientific knowledge and competencies in the process. Large research groups had access to custom laboratories as well as testing furnaces to facilitate practical experiments evolving around production of silicon by cost- and energy-efficient means (Sogner 2003). The on-

[4] FFF Ferrolegeringsindustriens forskningsforening was established in 1989 and financed by participating firms and the Research Council of Norway.

going research and experimentation within Elkem was strengthened by links to key research organisation such as the Norwegian Institute of Technology (NTH)[5] and SINTEF[6]. In addition Elkem collaborated with a number of international research environments (Tronstad 2011). The knowledge and competencies founded at this point in time were and still are central to most of the organisations active in solar PV industry in Norway today.

3.1.2 Global linkages

At Elkem`s research centre in Kristiansand a pilot plant which was quite unique was developed. This enabled Elkem to further establish a wide spun global network. Elkem ran tests and trials for the alloy-industry worldwide. Experimentation on pilot scale was highly advantageous in order to explore production characteristics and their potential associated costs at larger scale (Tronstad 2011). Experimentation with chemical processes at this level served as a link to both research environments as well as industrial partners. Elkem therefore was not only an exporter of commodities. The company also functioned as an R&D partner and developer of new processes and patented a number of processes that they themselves did not industrialise but sold on to customers across the globe (Tronstad 2011, Wicken 2009).

In the early nineties Elkem collaborated closely with Exxon Mobil in attempting to develop a new process for production of silicon for solar cells.[7] The arrangement was that Elkem was to do the metallurgical research and Exxon would pursue the following steps of the value chain. At that point in time there did not exist formalised business plans, market growth was slow and raw-material specifications (purity) and production volumes were far from satisfactory (Tronstad 2011). The experiments did however prove that the competencies at Elkem had potential and signalled future business areas and possibilities. The explorative activities did also form a broader network and important contacts were established.

Establishment and strengthening of networks with actors in polysilicon, electronics and somewhat later, solar energy industries was important (Tronstad 2011). The pre-production phase also was characterised by explorative ventures into new technological fields and markets through processes of strategic buy-ups of relevant firms. Amongst others Elkem bought the British company Crystalox in 1985 (Bjørseth 2011, Sogner 2003: 271). Dr. David

[5] NTH (Norges Tekniske Høgskole) is the predecessor of NTNU (Norges Teknisk-Naturvitenskapelige Universitet).
[6] The Foundation for Scientific and Industrial Research
[7] Note that Exxon had activities related to solar PV even before the 1970ies energy crises, and was an important actor in establishment of production of solar cells for terrestrial use through the establishment of Solar Power Corporation (Perlin 1999)

Hukin who specialised in lasers for the electronics industry, managed the company and developed processes for crystallisation of silicon. Crystalox became a leading producer of crystallisation furnaces for silicon[8].

Elkem did however experience a serious financial down-turn in the early nineties that lead to company restructuring. The decision was made to sell Crystalox. This reflected company strategy, which changed from exploring new markets and industries to strengthening existing core activities. A result was less attention to solar energy (Sogner 2003). Although Elkem in this phase was the largest producer of metallurgical silicon and did establish explicit strategic ventures into higher purity silicon, electronics and solar energy industry, the firm existed within a larger system that in sum created a critical mass and constituted an important industrial export segment in Norway. The establishment of the FFF is an example of this, and constituted a broader arena for formulation of critical problems and development paths for the existing industry. Out of an agency perspective we may speak of close links between producing firms and research environments that were dealing with specific questions related to core activities and competencies of firms. These actors and networks between them also mattered in the subsequent phases of development. Moreover, during this first phase solid knowledge foundation was established for future developments as well as the formation of important networks with research and related industries. Knowledge development in this phase was path dependent and oriented towards improvement as well as attempts at diversification based on existing knowledge bases. We may argue that actors linked to a prevailing regime made attempts at diversification, but were hampered from doing so due to incumbent firm strategy amongst others. At the same time the window of opportunity was not as markantly open as that of the following phase in terms of market opportunities which increased during the late 90s and more rapidly in the following decade (Jäger-Waldau 2012).

3.2 Formation phase (1994-1998)

In the previous section I illustrated how a strong ferroalloy industry was established in Norway that pursued paths of development of new and cost-efficient processes but also in direction of diversification. This section discusses the first ventures along the latter path.

[8] The company still exists under the name PV Crystalox and produces ingots, wafers and polysilicon for the PV industry.

3.2.1 The role of the incumbent regime during system formation

Alf Bjørseth was technology director at Elkem and was a central figure in the projects and groups working with silicon throughout the 80s, amongst others new means of silicon refining (Bjørseth 2011, Enger 2011). Previously he had held the post as research director at Hydro[9], another major Norwegian incumbent in the chemical process industry. He proposed venturing into production of silicon wafers to Elkem`s management and board in 1993. The initiative was however not followed up on due to Elkem`s financial situation at the time. There also existed a perception of instability and risk related to the solar energy industry, which provided an additional factor for not pursuing such plans (Bjørseth 2011).

Elkem`s unwillingness on the one hand and Bjørseth`s belief in a solar energy venture on the other resulted in him following up on such plans outside of Elkem, and resulted in the start-up of the company Scanwafer, the first solar energy firm in Norway in 1994 (Bjørseth 2011, Qvale 2012).

As Bjørseth had left Elkem, financing the start-up was a critical issue. Hydro proved to become important with regards to the mobilisation of resources. The main share of investments in Scanwafer came from Scatec (Bjørseth`s investment and development company) and Meløy Næringsutvikling (Meløy business development – started by Hydro and Meløy municipality), which at that point in time was owned partly by Hydro (Bjørseth 2011, Klitkou 2010). Norwegian banks and SND[10] were other key organisations contributing in financing the venture. SND demanded documentation of reliable markets for silicon wafers as well as bank guarantees and contracts with customers. In order to meet these demands Scanwafer representatives copied wafer specifications off the international market leader Solarworld and spent a long time and effort on convincing a Japanese cell manufacturer to sign a supply contract. Scanwafer was able to sign deals for shipment of volumes for the four first years of production, which made SND approve 25% funding of the start-up (Bjørseth 2011, Klitkou 2010).

Glomfjord industripark (located in Meløy municipality), which is a traditional industrial area in northern Norway that earlier had housed many of Hydro´s plants for fertilizers, was chosen as a location. The venture was not only motivated by the belief in a growing solar energy industry but also by the potential of locating production in Norway. Infrastructure, in

[9] Hydro is major chemical processing company, amongst others known for artifical fertilisers and its aluminium production.
[10] The state business and disctrict development fund, which was taken over by innovation Norway in 2004 (SNL 2013)

particular the access to production facilities, cheap electricity and cooling water, were of particular importance. The production of ingots and wafers is highly energy demanding. Access to energy was secured through a deal with Hydro Energi who had an existing close relation to Meløy Næringsutvikling (Bjørseth 2011, Klitkou 2010).

Scanwafer acquired its first production facilities as well as employees from Hydro in Glomfjord. Therefore Hydro did also contribute to the mobilisation of human resources. These were already trained within the process industry, which made retraining easier. A part of the deal made with Hydro was retraining of employees, backed by public funding (Bjørseth 2011).

The ties to Elkem did also remain important. Elkem had a 10% ownership in Scanwafer and collaboration on R&D continued. A range of previous Elkem employees also followed Bjørseth during the start-up of Scanwafer, bringing with them key knowledge bases supplementing the access to production facilities and skilled workers (Bjørseth 2011).

3.2.2 Innovation and knowledge flows in the formation phase

During the start-up of Scanwafer, contact with former Elkem owned Crystalox was renewed. Dr David Hukin, founder of Crystalox, was a key member of the team planning and constructing Scanwafer`s first plant in Glomfjord (Bjørseth 2011, Ruud & Mosvold Larsen 2005: 21). His speciality was crystallisation processes for crystals to be used in lasers, and was associated with the semiconductor industry through this (Bjørseth 2011).

The crystallisation furnaces implemented in the first Scanwafer plant were produced in collaboration between Scanwafer and the German company ALD. The company was specialised in vacuum technologies and amongst others produced a custom vacuum furnace. It had traditionally catered semiconductor industries, and did not have relations to the PV industry at the time. The technology was modular, and hence adaptable to differing production environments. The furnaces were customized for the existing production facilities at Glomfjord. Amongst others this involved the introduction of larger furnaces that allowed to quadruple capacity (as four crucibles could be started in the same "run" in a furnace) on the basis of a doubled investment. The goal of the ALD – Scanwafer collaboration was constructing more efficient crystallisation furnaces and the implementation of these became important for Scanwafer`s competitive ability. A long-term collaboration agreement was signed, which involved the purchase of a minimum amount of furnaces, in return of an exclusivity agreement. The collaboration continued to be important in the expansion phase as most of RECs new capacity additions used this technology. Scanwafer`s first plant, Glomfjord I, started production in 1997 (Bjørseth 2011).

Another key innovation activity during start-up of Scanwafer was construction of customized wire saw [11]. Again the collaboration with European companies was central. The Swiss company HCT was a key supplier of such production equipment both for the electronics and PV industry. Danielle Margadonna, former technical director at Eurosolare[12], was an expert on wafer sawing processes, and his experience played a key role in the development of customising wire saws for the first Scanwafer plants (Bjørseth 2011).

Summing up, the dynamics associated with the formation phase are characterised by activities closely related to the incumbent regime. They rest on the continuous learning processes associated with silicon production and the one hand and on continuous efforts at diversification on the other. The development during the formation phase indicates the key role of knowledge embedded in both local and international actors. Incumbents such as Hydro and Elkem became important during the formation phase in terms of mobilisation of resources and infrastructures. At the same time knowledge flows, from the electronics industry and their suppliers in particular were important to the successful established of solar PV as a new industrial branch in Norway. In sum, the formation phase was characterised by flows of knowledge in networks built and maintained by actors in the existing regime. The story above is also one of agency, given that the role of certain individuals seems to have mattered in the context of broader organisational and institutional settings, i.e. we can identify Bjørseth as a system builder figure (Hughes 1987).

3.2.3 Expansion phase (1999-2010)

The establishment of the company REC (Renewable Energy Corporation) in 1999 marks the onset of the expansion phase where more and larger companies operate within global PV markets. This phase also included the entering and emergence of new firms, both wafer producers and specialised suppliers, which expanded the PV TIS in Norway both in structural terms but also in terms of contributing to the development of the overall knowledge base. Section 5 discusses the functional aspects of system formation.

[11] The silicon ingots produced in the crystallisation furnaces are cut into thin wafers in the following process steps. Key to this is minimizing Silicon waste.
[12] Eurosolare was a subsidiary of Italian oil company AGIP (Bjørseth 2011).

Table 2 depicts actors within the Norwegian PV TIS, and shows their placement along the value chain ranging from raw-material supply to retail and development of solar PV plants. The table also includes main actors in research and development. The table illustrates how a range of experiments focused on the supply of raw-materials. Access to silicon raw-material constituted a major bottleneck for growth, and lead to price increases for several years (Goetzberger et al 2003, Ceccaroli & Lohne 2011). This increase is reflected in figure 1, which shows module prices for the period 2001-2012.

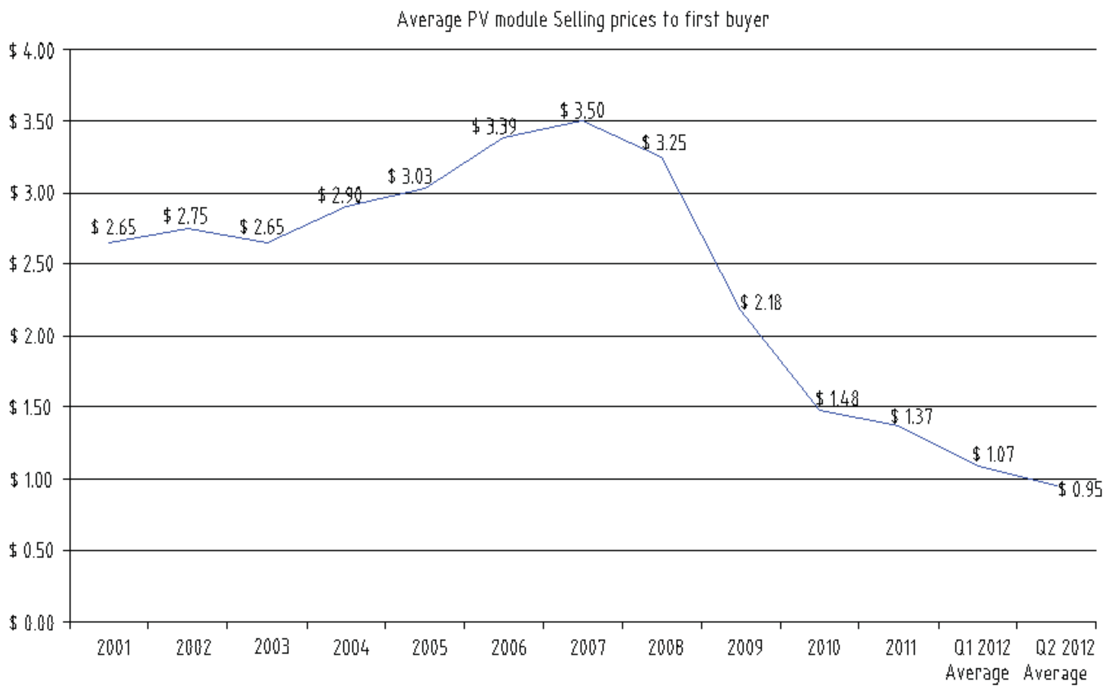

Figure 1: Average selling prices for Modules (USD) in $ MWp 2001-Q2 2012 (Source: Mints 2013)

Thw silicon bottleneck was critical not only for the Norwegian firms, but for the whole PV industry. In the expansion phase one of the key issues was access to sufficient to silicon raw-materials, and experimentation at this level can be seen as a response to this bottleneck. Many firms therefore perceived growth opportunities in this segment of the PV TIS.

Research and development	**Suppliers – raw-material**	**Suppliers - other**	**Producers of wafers/cells**	**Producers of models and systems**	**Plant owners and developers**	**Retailers**
SINTEF	Elkem Solar	Tronrud Engineering	REC	REC	Scatec Solar	Getek
IFE	Fesil	Vetro solar	Norsun	Innotech Solar	Differ	
NTNU	SiC processing	Prediktor	Innotech Solar			

UiO	REC	Eltek Valere				
NORUT	Metallkraft AS	Artech				
TEKNOVA	Ekro					
	Norwegian Crystallites					
	Washington Mills					
	CruSIN AS/ Saint Gobain					
	Silansil					
	Clean Silicon AS					
	HyCore					

Table 2: Actors in the technological innovation system for solar PV in Norway

In the following I discuss some of the dynamics underlying this development in empirical terms. I use examples of selected firms to illustrate learning processes and how and which types of technologies are used in the development processes.

3.2.4 *Expanding existing capacities*

REC was established as a holding company in 1999. At that point in time Scatec AS was the biggest shareholder in Scanwafer and invited the other shareholders Hafslund Venture and Lyse Energi to establish REC as a holding company. Both Hafslund Venture and Lyse Energi already owned the investment company Fornybar Energi AS, who in turn owned shares in Scanwafer. At start REC owned 12% share in Scanwafer, but did acquire full ownership in 2004. Another key investor in the emergence of REC were venture capitalists Good Energies[13] which also were key investors in German Q-cells which in 2006 was the world`s second largest PV manufacturer (Bjørseth 2011). Access to capital was therefore also secured by approaching investors in the global renewable energy sector. Today REC controls activities along the whole PV value chain, through its divisions; REC Silicon, REC Wafer and REC Solar.

At the time when the first Scanwafer plants were built no turn-key production lines were available, and most of cleaning and quality control was performed manually. As a result of a large increase in customer orders, the decision was made to make an attempt at full automation also at this step along the process. This was performed in an experimental way, amongst others involving employees that formed workgroups to formulate requests on how to

[13] Good energies are owned by the Brenninkmeijer family which amongst others own the retail chain C&A, and have a made a number of investments in various RETs (Bjørseth 2011).

develop and streamline the process. The advantage of pursuing such a strategy was based on how "…manual cleaning was a process that gave employees a feeling of how to handle wafers. They had the process in their fingers (Bjørseth 2011)".

Tronrud Engineering[14] was contacted to construct automation equipment based on the input of the work groups. This resulted in a fully automated cleaning and control line. At the time Scanwafer was the first PV wafer manufacturer to have a fully automated cleaning and control line, much to global surprise and interest. Scanwafer`s employees were actively engaged in the design process and the company also owned proprietary rights for these automation lines (Bjørseth 2011).

Scanwafer`s products were well received on the international markets, particular in Japan and Germany. Due to increasing demand, the decision was made to expand production and to build a second production plant. Glomfjord II started production in 2001, with a capacity (40MW) four times that of the first plant. The facilities were again constructed by Tronrud Engineering, and Scanwafer (now partially owned by REC) received proprietary rights (Enger 2011).

In terms of further expansion the ties to Hydro continued to be of importance as Scanwafer located their third plant in Hydro`s former magnesium production facilities at Herøya, in 2003. Again both infrastructure and employees came from Hydro, including financial support for retraining (Bjørseth 2011). The plant Scanwafer III was based on the same solutions as the two former plants, but did upgrade automation processes amongst others. Scanwafer IV was located next to Scanwafer III at Herøya. The plants were fitted with similar production lines, but compared to Scanwafer I, the process technologies and their efficiency had changed vastly. This for instance was manifested in wafer thickness, which was reduced from 330 micrometres at Scanwafer I to 180 micrometres at Scanwafer IV (Halvorsen 2008). This implies almost doubling of production capacity if material usage is kept at a constant level. Production capacity at the plants in Herøya was raised from 95MW in 2003 to 380 in 2006 (Halvorsen 2006).

RECs rapid expansion was taken to another level as plans were made to invest in new production facilities in Singapore 2008. The integrated plant (wafers, cells and modules) in Singapore opened in 2010, amongst them a 800 MW cell production capacity. The estimated construction costs amounted to 1,3 billion EUR (Stensvold 2012). Human and financial

[14] Tronrud engineering is a Norwegian supplier of automation equipment catering many different industries, including solar PV.

resources as well as overall and labour cost levels were argued to be favourable in Singapore (Enger 2011). Availability of qualified personnel from the semiconductor industry was stated as a particular advantage:

> "In Singapore were we operate, the semiconductor industry counts over 100,000 people just in that small town. When we needed our 1600 people, we picked from a base of 30,000 without any big effort on our behalf to attract applicants. In Norway, hiring from Hydro or Follum is something quite different (Enger 2011)."

Therefore, as REC were up scaling their activities, the opportunities for growth were perceived as better in Singapore than in Norway, amongst others due to the availability of skilled personnel.

There was also a strategic idea behind the move of RECs centre of activities to Singapore. China emerged as a major player, which challenged many of the existing actors in the industry, in particular due to the rapid drop in prices[15] from 2007 and onwards (Mints 2013). RECs strategy for growth at the time was linked to moving closer to locations with existing electronics industries and lower cost-levels (Enger 2011). Table 3 shows how REC emerged as the world`s fifth largest silicon and wafer manufacturer in 2011.

	Silicon producers	**Wafer producers**	**Cell producers**	**Module producers**
1	Hemlock semiconductor group (US)	GCL (CN)	Suntech (CN)	Suntech (CN)
2	Wacker (DE)	LDK (CN)	JA Solar (CN)	First Solar (US)
3	OCi (KR)	ReneSola (CN)	Trina solar (CN)	Yingli Solar (CN)
4	GCL (CN)	Yingli Solar (CN)	Yingli solar (CN)	Trina Solar (CN)
5	REC (NO)	REC (NO)	Motech (TW)	Canadian Solar (CA)
6	MEMC (US)	Green energy technology (TW)	Canadian solar (CA)	Sharp (JP)
7	LDK (CN)	Jinko Solar (CN)	Sunpower (US)	Jinko Solar (CN)
8	Tokuyama (JP)	SolarWorld (DE)	Sharp (JP)	Sunpower (US)
9	DAQO new energy (CN)	Trina solar (CN)	Hanwha Solar (KR)	Hanwha Solar (KR)
10	ReneSola (CN)	MEMC (US)	Jinko Solar (CN)	Kyocera (JP)

Table 3: Top 10 Silicon, wafer, cell and module suppliers. (Firms are ranked on production out put; tonnes for silicon producers and MW for wafer, cell and module manufacturers (Source for columns 1-3 (Solarpraxis 2012) for column 4 (IMS Research 2012).

[15] PV module prices dropped 70% from $3,50 per Wp in 2007 to below $1 Wp in the second quarter of 2012 in the aftermath of price increases due to the silicon bottleneck amongst others (Mints 2013).

3.2.5 New wafer producers

In the expansion phase, not only existing firms expanded production capacities. New firms also entered. Scatec`s subsidiary, Norsun was founded in 2005, the year Bjørseth left his position as CEO at REC. Again one of Norway's traditional industrial areas, Årdal, was chosen as a manufacturing location.

Hydro closed its oldest aluminium production line (the so-called Søderberg-line) in Årdal in 2007, which led to redundancies. Årdal municipality and Hydro Aluminium established Årdal Framtid AS to attempt to establish new industrial ventures in the region. The municipality provided some funding (70 million NOK out of a total 1 billion NOK investment). However, favourable electricity deals, good access to cooling water, access to skilled personnel were more important factors that influenced the decision for locating production in Årdal. Hydro went in as a substantial shareholder (Bjørseth 2011, Klitkou 2010).

As opposed to RECs wafer production, which mostly is multicrystalline, Norsun produces monocrystalline wafers. These have higher production costs, but higher efficiency, and were at the time of construction only assumed by some to sell well in advanced markets (Valmot 2006). This strategy did receive scepticism at the time of its introduction (Qvale 2011), but did prove to be advantageous as prices dropped rapidly (as illustrated in figure 1) and cell-efficiency started to matter more for the overall costs of a PV installation[16] (Bjørseth 2011).

The production equipment radically changed from that of REC, primarily due to close cooperation with the Finnish semiconductor firm Okmetic in design of crystallisation furnaces (Bjørseth 2011). Norsun established a licensing agreement that included delivering wafers only to PV markets. Norsun made long-term contract agreements for wafer shipments with SunPower Corporation with duration until 2019. They also supply market leaders Sanyo and others with wafers.

A key process innovation introduced in Norsun was a new way of wafer sawing. Norsun, together with Meyer Burger, developed a new sawing system using a diamond-coated wire, which uses pure water for cooling (as opposed to the standard use of liquid slurry containing silicon carbide) (Bjørseth 2011). Meyer Burger supplies various sawing solutions to the PV, semiconductor and optics industries (Meyer Burger 2013). The process is referred to as fixed abrasive wire sawing. Its advantages are argued to be the enabling of quicker sawing, the

[16] As the auxiliary costs (so-called balance of system (BOS) costs are linked to an increasing share of the total cost of a PV system, cell efficiency matters more than before because having more efficient cells would mean lower BOS cost per MW (Irena 2012, Bjørseth 2011).

reuse of sawing wire, no need to use or recycle slurry and easier recovery of silicon from sawing dust (Qvale 2011, Bjørseth 2011).

3.2.6 Cell production

In the growth phase REC expanded to include production of cells. Although being vastly different to that of wafer production, the inclusion of this segment was in part argued to be due to wanting to increase understanding of material and wafer characteristic at later stages in the value chain (Enger 2011).

Innotech Solar, another company in the cell segment emerged as a spin-off of REC. The company specialises in recycling off-spec cells. In the production of cells a range of deficiencies may arise, from structural cracking to purely cosmetic deficiencies. Many former REC employees are placed here, and the firm first grew in close proximity to REC facilities. The firm also established production in Halle, Germany and has gradually moved much of staff here (Tuv 2012).

3.2.7 Raw-material production

In the expansion phase the activities related to silicon were strengthened. Not only PV firms were preoccupied with developing new processes for silicon production. Traditional ferrosilicon producers were themselves entering the industry applying new process delivering new products specifically aimed at the PV sector. The following sections describe some of the attempts at this.

3.2.7.1 REC

One of the requirements for the Scanwafer – REC merger was sufficient material access. The perception was that securing access to raw-materials was strategically important to enable growth at the further steps along the value chain (Enger 2011).

In 2002 REC made the first step towards securing material access. REC made a move towards the Japanese firm Komatsu, who owned a polysilicon plant in Moses Lake US. Komatsu, an equipment and machinery supplier, did not have their core competencies within electronics and chemicals sector (Komatsu 2013). The plant was used to produce polysilicon for the electronics industry and Komatsu had initially bought it from Union Carbide (Enger 2011). REC, after a long period of pursuit, made a deal with Komatsu to buy the plant for 1$ (the price reflecting that shutting down a plant is highly costly) and to follow up on a large research project on new silicon production processes. Timing of this takeover was argued to be of high importance, given the down turn in the electronics industry at the time. The strategy behind the pursuit rested in belief in further growth of PV, a belief in future challenges in access to raw-materials and the weak markets for polysilicon. REC became a front mover internationally amongst actors in the PV industry to secure raw-material supply. In 2005 REC took full ownership of Komatsu`s second polysilicon plant in Butte, Montana (Bjørseth 2011). As depicted in table 3, REC grew to become the fifth largest global producer of silicon in 2011. It also was a highly profitable venture, in particular during a period of high silicon prices, linked to the raw-material bottleneck.

As part of the agreement for taking over the first plant in Moses Lake REC agreed to follow through on a large research project. This was linked to development of a new process for silicon refining based on a fluidized bed reactor, which had been initiated by Union Carbide (Enger 2011). This is a modification of the traditional Siemens chemical process route for silicon production. This modification reduces the high energy consumption associated with the Siemens process. According to REC, energy consumption may be reduced with as much as 80-90%. An additional benefit of the modification is that it allows for continuous production, whereas the traditional Siemens process needs to be done in batches resulting in periods of downtime in order to remove the finished silicon rods from the reactor (REC 2013). The final product is silicon granules as opposed to large silicon rods (which need to be crushed before using them in ingot production) and this enables a more efficient crystallisation process in the subsequent stage (Bjørseth 2011).

3.2.7.2 Elkem Solar

Even though the first ventures into solar PV took place outside of the confines of Elkem, the company did continue its pursuit of developing new processes of silicon refining. In 2001 Elkem Solar was established and marked a formalisation of these attempts (Tronstad 2011). By then the PV market had increased substantially. In addition there now existed domestic industrial activities.

Having made a range of previous attempts at developing this type of process was argued to be favourable because a range of potential routes could be excluded. In other words the development process was characterised by a range of trials and errors, and the process described below emerged as a result of these various attempts. This was characterised as a “sorting out” process (Tronstad 2011).

Elkem Solar was an early mover with regards to solar grade silicon based upon an upgraded metallurgical process, which marks a change from the traditional Siemens based processes. Elkem Solar applies a custom metallurgical route involving five main steps. First metallurgical silicon is produced using a furnace for metallurgical silicon production with minor modifications. The molten silicon then is mixed with slurry in order to remove impurities (boron in particular) in step two. In step three the silicon is purified further using wet chemical refining, whereby metallic impurities are removed. The silicon then goes through a horizontal solidification process which pushes out remaining impurities on the top section of the silicon block in step four. The last step contains surface treatment and cutting of the silicon block (Tronstad 2011).

The new solar grade silicon based on metallurgical processes needed legitimacy in a market previously dominated by electronic grade silicon. During Elkem`s early attempts producing solar silicon based on metallurgical processes in the 80s, testing and material characterisation was challenging. At that time the only way of testing material was analysing the efficiency of finished cells, and as a result it was challenging to gain understand which type of material characteristics that had effect on cell efficiency (Tronstad 2011).

When establishing Elkem Solar weight was put on development of chemical analysis methods that could enable a deeper understanding of which types of material impurities that impact on cell efficiency. In addition collaboration with a range of industrial and academic partners was important for testing and further development. Elkem Solar collaborated with the German company Q-cells (at a point in time the worlds largest silicon wafer producer with a good track record). Q-cells emerged as the largest customer as well as being a substantial owner of Elkem Solar (Martinsen 2009). Q-cells also took part in testing of Elkem Solar silicon (Hoffman et al 2008).

This is an example of how Elkem used its networks to initiate the collaboration. The testing was vital in establishing the viability of Elkem material in actual production of solar cells. Scientific knowledge also played a legitimising role with regards to using “experts” to ensure and prove the viability and usability of the new material. Scientific knowledge also plays an important role. Testing of Elkem silicon also was done by researchers at the University of Konstanz in collaboration with Elkem employees (Peter et al 2008, Peter et al 2010).

Elkem`s plant located at Fiskå was opened in 2009 and ran test operations in its first months. It has a production capacity of 6000MT. Elkem Solar claim a considerable reduction in energy consumption, using a quarter of the energy compared to standard Siemens processes, and is argued to be a critical advantage of this process in particular because it is associated with lower production costs (Tronstad 2011).

3.2.7.3 Fesil Sunergy

FeSil is another traditional producer of ferrosilicon in Norway that started pursuing development of a solar silicon production process based on an alternative metallurgical route.

Fesil Sunergy`s process is based on the standard carbothermic process for production of metallurgical silicon, but the main difference from that of Elkem is linked to the materials used at the onset of the process. In the process, carbon and silica materials with low impurity levels are used so that the initial raw-materials are purer than for standard metallurgical processes. High purity Carbon “Carbon Black” is replacing traditional coal and charcoal in the furnace (Wærnes et al 2006). This reduces the amount of impurities originating from the reduction material. Natural gas is used to produce Carbon Black (Tønseth 2009).

The Solsilc project was sold to the German chemical firm Evonik Industries AG in 2011 and Fesil thus pulled out of PV related activities. The sale included machinery and equipment, intellectual property rights and employees (Fesil 2011).

3.2.7.4 HyCore

Hydro also pursued the PV industry directly. HyCore was established as a joint venture between the Hydro and Belgian Umicore, a supplier of advanced materials serving automotive, electronic and PV industry. A pilot plant at Herøya in Norway was started in 2008 in addition to two pilot plants at Umicore`s plant in Belgium. The original plan was start of full-scale production in 2010. Nevertheless the company announced a stop in further research and expansion plans due to problems with the process technology. The company further argued that they perceived a saturation of solar silicon markets in the future and argued this to be an additional reason for stop in pursuit of further development (Gram 2010).

3.2.8 Emergence of specialised suppliers

In the growth phase a range of specialized suppliers emerged, often in close spatial proximity to established plants at Glomfjord, Herøya and Årdal.

3.2.8.1 Tronrud Engineering

Increase in production output and plant size involved new types of production equipment to facilitate larger production volumes. Application of automation technology for quality control, chemical treatment, washing, and packaging is one central aspect of this development. Tronrud Engineering has delivered production equipment for a range of Norwegian and international users. In particular Scanwafer`s and REC´s production facilities both in Norway and in Singapore have been fitted with technology from Tronrud Engineering. The construction processes took place in close cooperation with users, where customizing the equipment for particular needs is central, as illustrated in section 3.2.4 (Bjørseth 2011, Enger 2011, Fernandes 2011).

3.2.8.2 Si Pro AS

Si Pro AS recycles off-cuts from ingots and wafers, which normally would go to waste. Si Pro AS have located production facilities alongside RECs plants both at Glomfjord and in Tuan, Singapore (Glomfjord industripark 2012a).

3.2.8.3 Metallkraft AS

Metallkraft recycles slurry used in wafer cutting processes. The traditional wafer cutting process is dependent on a viscous fluid, referred to as slurry, in order to make cutting more efficient. The slurry consists of abrasive silicon carbide (SIC) and glycol, which acts as a coolant. Huge amounts are required in the processes but the slurry is quickly contaminated by silicon dust and metal particles from saw wire (Bjørseth 2011).

Metallkraft has developed technology to recycle slurry and established plants in Norway, Singapore and China. The company was founded by Knut Henriksen, former R&D vice-president of Elkem, where he had pursued research on recovery of silicon carbide slurry and silicon from the slurry (Metallkraft 2013).

3.2.8.4 SiC processing AS

SiC processing AS, a subsidiary of German SiC processing GmbH, also performs recycling of cutting slurry, and established production facilities in Norway close to RECs plants at Herøya and Glomfjord (Glomfjord industripark 2012b).

3.2.9 Summing up

In sum this section has illustrated how the expansion phase was characterised both by the entry of a range of new actors, both in terms of manufacturing and suppliers, as well as of rapid growth of existing activities.

Table 2 illustrated how Norwegian actors are distributed along the value chain for PV. Compared to wafer and cell manufacturing capacities in many other countries (see table 3 for distribution of top manufacturers) the number of actors in Norway is low. REC does however have a large manufacturing capacity, which put them in the global top ten of silicon as well as wafer manufacturers in 2011. In part this was achieved through the wide range of process innovations made from the onset in the Scanwafer plants, such as custom furnaces and wire saws.

In addition a key dynamic in this phase, with impact on the global TIS, was the experimentation with new ways of making solar silicon. During the expansion phase there emerged a range of actors that attempted to, and some succeeded with, developing a diverse set of supply capacities. In particular this goes for entrepreneurial experimentation with new ways of production of silicon raw-material specialised for PV purposes, such as the modification of metallurgical process routes. Informants also attribute the lack of specialised raw-material supply and high growth in demand as core motivations for making the moves into this market segment (Bjørseth 2011, Tronstad 2011, Enger 2011). This phase thus marks a manifestation of the activities and experiments already embarked upon in the pre-production phase. Also a range of activities were related to handling and usage of raw-materials in production processes, such as recycling. A range of suppliers entered, often in close proximity to the established manufacturing facilities in traditional regional industrial areas in Norway.

However in the aftermath of this expansion phase, the global PV industry headed towards a dramatic period. Again raw-materials were at the centre of attention, although this time a perceived over-capacity challenged the margins of raw-material manufacturers and the viability of establishing new manufacturing capacities. Overcapacity however was a critical issue within the whole industry including wafer and cell production. This marks the entering into a down-turn phase, which is the focus of discussion in the following section.

3.3 The downturn – sunset for solar PV in the land of the midnight sun? (2011-present)

In the aftermath of a long period of entrepreneurial experimentation and rapid industry growth, both in terms of firm and overall industry growth, the Norwegian PV industry, like that of many other countries (Photon 2012, Schwarzburger & Morris 2012), experienced a downturn compared to the previous phase.

This new dynamic primarily became evident as China emerged as the dominant PV manufacturer (Enger 2011, Bjørseth 2011, Schwarzburger & Morris 2012), which led to a massive increase in global production capacity and a rapid price drop (Mints 2013).

In the downturn phase the most salient development in Norway was the close down of RECs domestic production capacity. This was a gradual process starting with lay-offs and reduction in manufacturing. Starting in 2011 REC reduced operations in the oldest plants in Glomfjord, where all production eventually was closed down. In 2012 the last REC plants at Herøya were closed down (Andersen & Stensholt 2012). The close down took place in spite of attaining large cost reductions in production over a short period of time (Riisnæs & Bjørndal 2012). The final stab came as the Norwegian division of REC Wafer filed for bankruptcy during the summer of 2012. REC closed down all production capacity in Norway (Dahl 2012). The large production facilities built in Singapore during the growth phase were however upholding and further strengthened (Enger 2011, Stensvold 2012).

RECs close down had serious extended effects on suppliers. Tronrud engineering, which had delivered important production and control lines to most of RECs production facilities in Norway and in Singapore also reduced their PV-related activities (Enger 2011). In addition Metallkraft and SiC processing abolished their activities in Norway, but Metallkraft upheld their activities in Singapore related to RECs plants (Metallkraft 2013). Even Silicon suppliers, such as Elkem solar also had to lay off parts of their staff and temporary close down parts of production (Tronstad 2011).

In interviews conducted in 2011 (during the PV crisis) informants indicate differing views on the future of solar energy in Norway. Some believe in a future for solar PV, but admit that it will be challenging in the absence of REC as an important driver and hub for suppliers and other actors (Bjørseth 2011). Others express belief in that solar activities will become reduced locally, but that the knowledge bases, in particular those linked to material characteristics, melting furnaces and crystal growth may become important for new industrial ventures such as growing crystals for LED screens (Nielsen 2011). Such a strategy would build upon the strengths in material technology and not the persistence in PV activities, i.e. a continuation closer to the original path related to materials.

Others quite explicitly express belief that the downturn is a result of Chinas rapid growth:

> "…we have been outrun because the big nations are pursuing this (Solar PV). It is quite clear that if you want to go into details about why Norway has been outrun it has to do with how when competition becomes so fierce it is just the very best that will survive… Norway has not been able to keep up in this process. For the world solar PV has been through a revolution and has never looked brighter. For Norway it does not look bright (Enger 2011)".

This quotation reveals an understanding of the Norwegian PV industry as incapable of keeping up with competition from bigger countries including China. The view that Norway has been unable to keep up should be seen in conjunction with RECs overall strategy, linked to how their manufacturing capacities grew outside of Norway.

The reduction in industrial activities also was expected to have extended effects and implications for the whole TIS, including the substantial efforts in building R&D capacities related to PV. Worries are being expressed for the research institute sector in particular:

> "…if there is no PV activity in Norway, then the research council hardly will allocate further funding, at least not on the scale that they have done. If there is no PV activity in Norway there won`t be any contracts for the institutes. They will die a quick and painful death (Bjørseth 2011)."

The view taken here is thus that the presence of industrial actors is important for upholding activities related to knowledge development, and perhaps the institutes sector in particular, which has invested massively in developing capacities for PV (Hundere 2011, Ibenholt 2011). Reduction of industrial activities locally may therefore have pronounced impacts on the overall dynamics of the solar PV TIS in Norway.

As firms differ in terms of production techniques and end-products, the crisis has struck these in different ways. Norsun for a short period had to close down parts of production, but did secure new contracts that enabled production to continue (Qvale 2011, Bjørseth 2011). As mentioned, Norsun produces high-efficiency monocrystalline wafers, which constitute a somewhat differing market segment than mainstream multicrystalline cells. It is pointed out that such a strategy – competing on quality and efficiency rather than production scale – was perceived more viable than competing in the mainstream market with Chinese competitors (Bjørseth 2011). Introduction of new process innovations, such as introduction of the diamond coated cutting wire however shows initiatives at competing on the basis of knowledge, skills and innovation rather than mere scale and cost.

Given the fierce competition on costs firms are attempting to compete in terms of process innovations. One way of doing this is through search strategies closely tied to the electronics industry. Scatec, which is Norsun`s parent company pursues this strategy:

> “For a long time we have had the philosophy that the next quantum leaps in solar PV will come from technology that has its origins in the electronics industry. The best technology for electronics can be found in Silicon Valley. Therefore we got engaged in a venture capital firm in Silicon Valley, which systematically searches for start-ups in the area. So then we made a deal, we invested in the company and said that we needed access to all the companies that they are surveying (Bjørseth 2011).”

Scatec`s strategy in terms of search activities thus is linked to direct pursuit of new developments in the electronics industry. Investing in a venture capital firm enabled to structure search activities, and the venture capital firm can be said to serve as a link or gatekeeper (Cohen & Levinthal 1990). The links from PV to electronics are therefore understood quite explicitly, and this impacts on the firm strategy.

One such quantum leap could be to Scatec`s pursuit of a radically different module production method related to:

> “… producing modules directly from gas. This is the most radical that we have seen. It would halve the need for capital both for manufacturing equipment and thus for the entire value chain. This would in turn enable us halve module prices (Bjørseth 2011).”

This process at a pilot stage, but indicates a further intimate link to the electronics industry. Moreover, the overall strategy is similar to that of incumbents throughout the previous phases: to introduce new and cost efficient processes.

REC is also pursuing a similar strategy. While REC moved its manufacturing and R&D capacities to Asia, their search and exploration activities linked to technologies “…further on the horizon (Enger 2011)” were also located in California.

Lastly, dynamics are also occurring in the downturn period, and these are intimately linked to those of the overall TIS. As a result of the rapid price decline for solar PV investments in PV installations are becoming viable in an increasing amount of markets (Bjørseth 2011). A further development during the downturn phase was linked to how actors moved towards upper levels of the value chains, as some firms began to expand their activities in developing utility scale solar PV parks. This type of activity had existed for some time. For instance Statkraft (Norway's largest energy supplier that also owns (amongst others) hydro and wind power plants in a range of European and other countries) for a short period had activities in building solar parks, but chose to withdraw from these due to strategic reasons (Vatnaland 2012).

Scatec Solar, a subsidiary of Scatec, drove the hitherto largest activities in this field. Building utility scale parks not only in feed-in tariff driven markets[17], but also in Hawaii and African countries heavily expanded the activities in this segment during this phase (Bjørseth 2011). This not only marks a change in the setup of the PV TIS, but also exemplifies the competitiveness of PV in selected markets without support of feed-in tariffs. It does also indicate a way of attaining increased user-producer linkages.

4 Analysing the Norwegian PV emergence out of a path dependence perspective – the regime as a locus of change

How does the case of PV TIS emergence in Norway resonate with the notion of path dependence? In the case of PV in Norway path dependence is a concept primarily descriptive of how history matters within the context of the Norwegian ferro-silicon industry, as it depicts learning and search processes for new production methods within the path of silicon production, spanning decades. These processes have been tightly coupled to core business activities. Hence we may view the above as a continuous incremental transformative process involving a wide range of Norwegian industrial actors as well as research environments in a broad learning process centred around discovering, developing and implementing cost efficient production processes of silicon at increasing purity levels. In the expansion phase in particular the emergence of a range of specialized suppliers becomes evident. Many of these are preoccupied with lower levels of the PV value chain. Incumbent firms such as Elkem and Fesil entered the PV TIS at a moment when it was perceived to be linked with sufficiently large markets. These firms did not move very far away from what may be considered their core competencies, raw-material production. Entry was however also enabled by long-term search, knowledge development and experimentation efforts. The companies did have on-going learning processes with particular focus on delivering purer silicon products by cost efficient processes. In that sense the development process is path dependent because change

[17] In fact investments in non-FIT markets are argued to be beneficial due to less dependence on state-controlled reductions in tariff structures (Bjørseth 2011).

(in the sense of emergence of new processes and products) is influenced by what is (continuously) learned in the past and does not constitute a radical change in products.

Change, in this case, however also includes a “branching” or diversification process whereby a new “branch” – a new TIS is created. This includes adding qualitatively new dimensions to the established patterns of production linked to the existing regime. Most notably this diversification process included the venture into a new technological field - solar PV technology. This entails moving into areas previously unexplored within the Norwegian context. The incumbent firms were however not first movers in this regard. Elkem`s unwillingness to move into the PV industry in the 90s is descriptive of this. The first ventures into solar PV hence were taken outside of the boundaries of the large companies, but with close links to them.

At the same time the development of solar energy in Norway depicts a development where heterogeneous sources influence the outcome, not only what is learned within the confines of the actors in the ferro-silicon regime. The processes of “branching” as well as the new ventures along the old path are dependent on factors outside of the initial path.

We may identify (at least) two paths of relevance for the transformation. The first may be labelled a chemical process industry path. This was a central path in Norwegian industrial structure, in which the production of ferrous metals and ferro-silicon has been at the core. Continuous learning processes going on over decades and including substantial investment both in R&D, production facilities and infrastructures characterize this path. The long term learning processes were coupled to search for cost efficient methods to produce increasingly pure silicon.

The other, a solar path were the usage of silicon as the dominant raw material has been stabilized over the last decades. There exist several materials that can be used in the production of solar cells. Many of these even have higher potentials for absorbing sunlight (Goetzberger et al 2003) but are often scarce and/ or associated with high costs (US DoE 2012, Marstein 2011). Irrespective of this, silicon has remained the dominant material (Hegedus & Luque 2011, Ceccaroli & Lohne 2011). This is not only due to its widespread availability but also due to its tight linkages to the semiconductor industry, which also play a pivotal role for its dominance.

We may describe this as a solar path, which is characterized by using silicon as the dominant raw material for producing solar cells. Path dependence also relates to how production along the entire value chain is adapted to using silicon. The fact that Norwegian companies have found it viable to enter into the solar energy industry is therefore also related to a particular set of path dependent dynamics occurring within the system for solar energy over time.

It is in the crossing of these paths that we may identify origins of the industrial transformation presented above. The semiconductor industry constitutes the meeting point of the two paths, i.e. both the PV and the electronics industries share the trait of using high purity silicon and Norwegian actors became linked to both through intermediate linkages and networks. Although Norway never became a producer of polysilicon for the semiconductor industry, the producers of ferrous silicon did have tight networks to the polysilicon industry and therefore also some ties to the semiconductor industry. The actors created networks and couplings to international actors within the polysilicon industry as well as the solar PV industry. These networks provided both flow of knowledge and the potential for discovery of new business opportunities, which in turn created a foundation for search processes for higher purity silicon as well as search for new business ventures. Thus the crossing of the paths was facilitated by actors that were embedded in the existing regime who mindfully deviated from the original path (Garud & Karnøe 2001) and actively pursued development along a new branch and thereby enabled a process of diversification within the existing process industry. This was enabled by persistent activities on the original path, as well as how the existing regime and associated path functioned as a focusing device.

4.1 Path dependence, regimes and search characteristics

Given the development depicted throughout section 3 there is good reason not to disregard the dynamic characteristics over time seen associated with a regime. In this context path-dependence may be a source of dynamic change rather than a source of a lock-in.

The above highlights how the regime becomes the locus of change, in particular by persistent knowledge development, networks and actors, which in turn become key to “branching” processes. It also tells a story of how regimes, or rather actors linked to a prevailing regime, were active in searching beyond the immediate technological boundaries related to the existing regime. Through searching these actors establish networks that in turn are important for facilitating knowledge flows. Actors linked to a regime may search because of landscape pressures or because actors are influenced to search in certain directions by discoveries or opportunities to utilize their established knowledge bases in new contexts.

Landscape or selection pressures posed upon the existing regime were however not made explicit given that the transition context was characterized both by uncertainties of problem scenarios and development paths. Given that Norway`s electricity generation by and large comes from renewable hydropower (SSB 2013a), we may argue that no particular selection pressures were articulated towards the regime in terms of climate change[18] or energy security (at least during the preproduction and formation phase). The chemical process industry did however face increasing uncertainty in the aftermath of deregulation of the power sector in Norway (Wicken 2011). The role of uncertainty in itself, in particular between the two formerly intimately linked sectors of electricity and the chemical process industry may be viewed as a type of selection pressure without a clearly defined development path. In other words the role of uncertainty for the chemical process industry characterized by uncertainty about future electricity prices constituted a type of selection pressure, although not very clearly articulated and with few change scenarios attached to it.

The lack of a clear articulation of a problem and development path scenario may also serve explanatory to the downturn in the PV industry in Norway. Given that its emergence was a bottom up development, in the absence of deeper public sector involvement, without a clearly defined problem and response this may challenge the persistence of transitional processes when the process of change is not embedded as a problem solver for a broader societal challenge.

In sum this section has underlined the importance of path dependence and dynamic of existing regimes for emergence of PV in Norway. Uncertainty in transition context however challenges the viability of the newly emerged industry. In the following section I am using the innovation systems perspective to discuss some of the underlying processes of emergence, growth and decline of PV in Norway.

5 Building a technological innovation system for solar PV – a knowledge flow perspective

The conceptual perspectives on regime change discussed in section 2 opened up questions related to which processes and mechanisms that are at play in endogenous regime change. We may envisage this sort of change to involve the emergence of new technologies within a

[18] Plans were made to tax emissions in the energy intensive industry. Kasa (2011) does however show how the parts of the industry succeeded in avoiding taxation of emissions due to promises made to reduce emissions by introduction of technical change.

context of established industries, institutions and actors. Several questions open up given the intimate relation between the existing regime and the emergent TIS, and they relate to which type of processes that were at play in the system building process for PV in Norway.

In this section I am moving the discussion to how new technologies emerged within the existing context and take the perspective of system building to analyse the dynamics associated with the emergence of the PV TIS in Norway. Therefore the aim of this section is to discuss how a TIS for PV was built in Norway, and I am primarily focusing on how diverse sets of knowledge were combined during this process. I am using the notion of knowledge flows to illustrate how knowledge was drawn from a diverse set of systemic contexts and how it influenced the emergence and functional dynamics of the system. The main purpose of this is to analyse how existing clusters and sectors impact on the dynamics of the Norwegian PV TIS. This is thus an investigation of which sort of processes that were at play during formation of the system and how exogenous sources become internalized in the system and impact on its dynamics.

The emergence of PV linked to the existing process industry regime can be viewed as the formation of a new TIS nested within the context of an existing regime. In order to portray the dependence on knowledge flows from external systemic contexts figure 2 illustrates the relation between the new TIS and aggregate system levels.

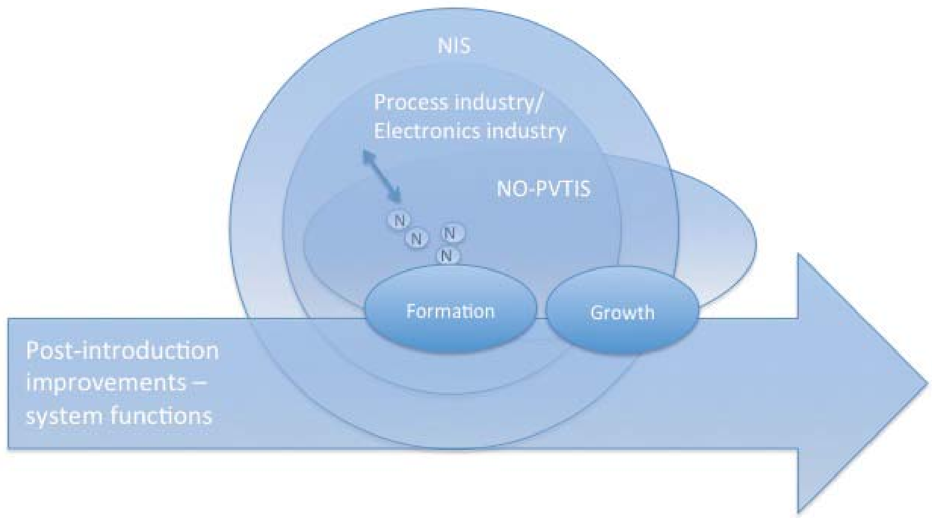

Figure 2: Norwegian PV TIS and associated system levels

As with other evolutionary perspectives on innovation we may draw analogies to biology. We may use the analogy to human conception, embryonic development and birth to describe the links between the different levels and the dynamics of the underlying processes of improvement. We can look upon the regime as the womb wherein a new offspring (a new TIS) was conceived, formed and grown. The new TIS was actively created by actors linked to the prevailing regime in search of new business ventures and diversification, i.e. by entrepreneurial experimentation. The regime provided an important protective environment in its emergence and “nursed” the new TIS with knowledge and resources, which also gave it its particular characteristics (for instance the strong focus on processes for raw-material refining). These ties to the regime did not get cut off at birth, i.e. during the process of system formation. Just like children and adolescents depend on parents or caretakers, the new system depended on regime knowledge, networks and resources for a long period of time and this can be illustrated by how the networks established in the regime proved important also for dynamics of the new TIS and in the way regime infrastructures were taken into use.

As the system was formed and expanded it started living its own life and attained a set of specific dynamics, manifested in more pronounced system structures (actors and networks) and processes (in terms of knowledge development, resource mobilisation and entrepreneurial experimentation directly linked to the new TIS). Therefore even though the system building process was dependent and succeeded in constructing and aligning these diverse sets of knowledge bases from related industries (Porter 1990), a range of additional processes were at play.

The presence or absence of these system functions can help identify systemic strengths or weaknesses within a particular empirical context. I am discussing those of importance either because they were fulfilled or because they lack(ed) as a critical component for system dynamics. Therefore, although focusing on the knowledge flow dimension of system building I am also discussing how the existing process industry and other systemic contexts impacted on other systemic functions, for instance that of search, resource mobilization and legitimacy.

In the following I am focusing on three aspects of building the Norwegian PV TIS: (a) how regime dynamics and knowledge flows were instrumental to system formation (b) how this impacts on the system dynamics as the TIS is growing, and (c) how the TIS performs in terms of processes as it evolves into a system containing internal dynamics.

5.1 Modes of knowledge flows in formation of the PV TIS in Norway

This section uses the notion of knowledge flows to depict and illustrate the dynamics between different systemic context, discussing how knowledge was drawn from external system context by processes of exploration and exploitation.

Inter-systemic knowledge flows may identified in the interaction with two systems in particular, namely that of the chemical process industry (the existing regime) and that of semiconductors and electronics. During all phases presented throughout section 3 the links to semiconductors and electronics become evident. In the formation phase the use of equipment and components normally used in semiconductor production constituted embodied knowledge flows. The inclusion of embodied artefacts did however also necessitate the addition of flows of disembodied knowledge, primarily by use of consultants that adapted manufacturing equipment and components to the particular processes of wafer production for PV processes. For instance in the formation phase the furnaces purchased from ALD, necessitated adaptation to the specific production processes at Scanwafer`s plant. Here the consultancy of David Hukin became important as a mediator between different knowledge fields.

In the same plant and in similar ways the wire saws bought from HTC were adapted to the local production context by means of both embodied and disembodied knowledge flows. Again a wire saw manufacturer, at the time mainly catering the semiconductor industry, was used as a partner in developing custom technology at the first Scanwafer plant. Here the consultancy of Danielle Margadonna became central in developing custom wire saws in the first Scanwafer plants. In both of these cases existing knowledge embedded in artefacts therefore was adapted to a new production context.
Flows of knowledge were not only present in the emergence phase, but also in the expansion phase. The link to the semiconductor sector is evident in the Norsun plant in Årdal, where a licencing agreement for crystallisation furnaces with a semiconductor firm allowed production of high efficiency mono-crystalline wafers.

We can also identify knowledge flows in the mobility of system actors and individuals. A range of individuals, including Bjørseth, had backgrounds in the major incumbents in the chemical processing industry. The role of disembodied knowledge flows in personnel is another example. Here the role of the existing process industry regime provided an important facilitator. The first Scanwafer plants took over former Hydro employees. These were unfamiliar with PV production processes, but did have experience with chemical industrial processes. The staff was instrumental in forming working groups, which became influential to development for the development of the first quality control and cleaning lines established in the first Scanwafer plants. These in turn brought along with them disembodied knowledge forms that played a role in how production and quality control lines were constructed. Therefore the mobility in terms of skilled personnel constituted another means of knowledge flow.

In sum a range of knowledge flows from a diverse set of sectors and industries played a role in the system formation process. This goes for both embodied and disembodied knowledge. The need for these knowledge flows illustrates how the diversification process depended on multiple sets of knowledge in order to enable system building. The system building process, and in particular the role of the existing regime, underlines that there existed a recipient apparatus, an existing absorptive capacity (Cohen & Levinthal 1990) in the existing regime to make use of the new knowledge and put it into practice in new production settings delivering new types of products. Moreover this knowledge was actively drawn from system contexts external to the existing industry and involved exploiting networks to facilitate these flows.

5.1.1 The role of networks and weak ties for facilitating knowledge flows

Knowledge flows that enabled the construction of new production plants, new raw-material processes and indeed formation of a new TIS within the Norwegian context took place in interaction amongst a range of different actors operating in different but interlinked sectors. Networks, in particular those established by actors in the existing regime, therefore played an important role in facilitating these knowledge flows between these systemic contexts.

Not only the apparent strong links to former colleagues and partners such as Crystalox and David Hukin were important as they provided entrepreneurial activities with critical knowledge inputs. These strong links also facilitated knowledge flows in weak ties (Granovetter 1973) that also played a critical role in the system building process. The importance of these weak ties can be illustrated in the embodied knowledge flows from the semiconductor sector in particular. These knowledge flows were critical to the system building process, but did not come from existing networks with strong ties. Rather intermediate links, in particular those formed in activities related to the path dependent process of developing and operating in silicon refining were instrumental to knowledge flows from actors with weak ties to actors in the existing regime. For instance the use of consultancy services were key intermediaries.

These networks were highly important in the formation phase, but remained important for several actors in the newly formed TIS and thus important in several of the phases described above. Firms also use made use of other knowledge sources such as taking part in industrial networks. Such networks provided firms with opportunities to gain know-how and know-who. The testing of Elkem's solar grade silicon which took place in cooperation with the German company Q-cells was a way of legitimising the new product and rested on important know-who in order to facilitate trust.

Additionally firms used joint venture strategies when experimenting with production of solar grade silicon. Hydro and FeSil both started joint ventures with companies abroad, with experience from electronics and solar PV. Aside from reducing risk, these joint ventures also were a way of increasing know-how and capital.

In sum networks established by actors in the existing process industry regime played a pivotal role in facilitating and enabling knowledge flows which in turn were critical for the process of system building. In the following section I discuss other important process development underlying system building and current dynamics.

5.2 Critical processes in building a PV TIS in Norway

Having discussed the role of knowledge flows and networks this section moves to a discussion of how the existing regime impacts on some of the critical processes that were underlying during the process of system building as well as a discussion of its current dynamics.

5.2.1 Developing and diffusing knowledge for solar PV

Knowledge development and diffusion is understood to lie at the core of a TIS as the evolving knowledge base determines emergence and growth of the system (Jacobsson 2011). The production of silicon and manufacturing of wafers and cells involve complex combinations of knowledge bases, which necessitated the flow of knowledge from related industries and sectors. The complexities arise because of the need to combine various forms of knowledge. We may argue that the combination of various knowledge forms was important to the formation of a PV TIS and the knowledge flows presented in the section above facilitated establishment of critical knowledge bases.

If we use Lundvall & Johnson`s (1994) classic knowledge taxonomy to analyse the combinations of knowledge forms it becomes evident that system actors have succeeded in combining these over time. Firms established and maintained important know-how and experience based knowledge bases through production of metallurgical silicon. The firms associated with metallurgical silicon production had continuous search activities for cost-efficient methods to produce higher purity silicon. This is an example of how firms experimented and gained experience in production. In this way the existing regime impacted on this functional dimension of the system in particular because the path dependent learning process allowed a strong knowledge base to establish within the metallurgical field. This knowledge base also proved important for development of new types of processes for production of solar-grade silicon.

Experiments with new processes were supplemented and strengthened by the creation of research laboratories. The couplings of experience based know-how to scientific know-why becomes evident in the creation of research laboratories in firms as well as in the cooperation with external research environments and other firms, such as the establishment of the FFF. Flow of knowledge and collaboration between firms and research environments was important to gain increased understanding of what goes on within melting furnaces (know-why) as well as how to make these process cost-efficient (know-how). In this instance R&D and scientific knowledge functioned as a problem solver in established industrial production (Mowery & Rosenberg 1998). Existing production therefore became an important input to the definition of and nature of R&D activities.

Collaboration with research environments is nevertheless only a part of the innovation processes and the participation and exploitation of networks to facilitate inter-systemic knowledge flows is a way in which diverse sets of knowledge were integrated and adapted in the system building process. Know-who was critical in facilitating these flows. In turn collaborations and networks also have provided opportunities with regards to establishing not only joint ventures but also gaining know-how vital to creating production facilities.

5.2.2 Regime impact on the direction of search

Influence on the direction of search is related to how firms or other organisations are influenced to discover opportunities within the TIS or are provided with incentives or pressure mechanisms to make them willing to invest. Influence on the direction of search therefore relates to identification of factors that influence search and investment behaviour (Bergek et al 2010). The story of PV emergence in Norway is one of incumbent firms and spin-offs entering and developing a new TIS. We may therefore ask what the driving factors for establishment of a PV TIS were, and what led firms to pursue solar PV in the first place?

A primary driver for firm search activities in early stages was affinity and networks with related industries and technologies. On the one hand this goes for the electronics industry, and for the early global attempts at industrial growth within solar PV on the other. Search for development of cost-efficient silicon production processes enabled linkages to actors embedded in the electronics and PV industry. Incumbent actors linked to the existing regime such as Elkem were indirectly linked to the PV industry through its silicon related activities. It was also through these networks that actors became linked directly to PV activities such as Elkem`s continuous attempts at developing processes for production of solar grade silicon. Together these links impacted on the search directions of incumbents such as Elkem.

Over time there has existed a strong focus on silicon-based technologies and this does indicate that the general search direction is related to the dominant technology type within the global PV industry. We may view the entry of new actors related to specific aspects of this technological segment for instance in terms of raw-material production and associated specialised suppliers as a response to dynamics associated with this path.

Another key driver of search activities was the formation of markets - internationally. In the formation phase, were actual firm establishment took place the formation of policy driven markets did constitute a primary incentive mechanism. Japan and Germany in particular constituted key markets during the formation phase (Bradford 2006). This marked a change in uncertainty in terms of market potential, and signalled growth in markets beyond those of experimentation in niches.

Therefore the links to the overall development within solar PV globally constituted an important incentive for search and consequential firm entry. Visions and expectations (van Lente 1993) is one key factor influencing the direction of search. The growth figures and the understanding of future growth patterns constituted an important dimension to how expansion of firms as well as entering of firms evolved over the expansion phase in particular. This may be argued to particularly so during the expansion phase, where price increases moved along side rapid market growth as depicted (Mints 2013). Incentives for entry may be argued to have been particularly strong at this stage.

5.2.3 Resource mobilization from the existing regime

This process relates to the ability to raise financial and human capital in order to facilitate growth of the TIS (Jacobsson 2011). In most of the phases, but predominantly in the preproduction phase and the formation phase, resource mobilisation was drawn from incumbents. Elkem and Hydro in particular were key actors in facilitating and financing search ventures that later constituted the base for solar PV in Norway.

Elkem, and the cluster of firms, research organisations and other actors coupled to silicon refining, ware part of the process industry regime which for some time was world leading both in terms of competence and scale. Moreover, this industry was tightly linked to the expansion of the power sector, and was part of the post-war boom in Norwegian industry expansion (Wicken 2011).

Elkem and Hydro played critical roles during the start-up of Scanwafer. The flow of knowledge and competencies embedded in individuals does seem to have mattered not only during the initial emergence, but also throughout the evolution of the industry - most notably by attracting competencies and resources from the incumbent firms. More so the start-up of specialized suppliers seems to indicate a similar tendency were knowledge flows move between firms, and actors move out of existing firms to start new ventures. REC as the largest player within the PV TIS in Norway seems to have played a critical role, not only with regards to becoming a customer, but also in being a knowledge source, in terms of mobility (cf. Innotech in section 3.2.6).

The resources, both financial and human, drawn from incumbents became central to emergence of solar PV in Norway. Not only did Elkem contribute with investment capital in the establishment of the first Scanwafer plant, but continued to support through ownership. Moreover, Hydro also played an important part in terms of financial resources through the business development firm Meløy Næringsutvikling as well as securing cheap access to power through Hydro Electricity.

An important point to highlight in relation to the mobilisation of resources is the broad role played by the existing regime in terms of facilitating resources, infrastructures, personnel and energy. During the formation period in particular resources were drawn from actors in the existing regime. The reductions in productions capacities in the process industry had left many production facilities standing empty. Manufacturers of solar PV thus came in to fill the gap, and therefore gained favourable deals when taking over infrastructures and personnel. In that way the existing regime impacted quite substantially on the mobilisation of resources over time, both financially as well as in terms of human resources and not the least in terms of infrastructures. Most of the manufacturing facilities used by Scanwafer, REC and Norsun were old Hydro plants for instance. This type of inter-systemic link existed well into the expansion phase as Norsun established their production facilities in former Hydro plants in Årdal.

In terms of human resources a range of former Elkem and Hydro employees became central to both establishment and growth of the PV industry. This goes for personnel at all levels. Moreover, many of those holding management positions, R&D management positions, and starting entrepreneurial ventures had experience from incumbents such as Elkem and Hydro. All informants state that the knowledge established around silicon production was critical to formation of firms and research associated with solar PV. Thus the formation phase was largely dependent on the knowledge bases, networks and organisations established during the pre-production phase.

It must be mentioned that the mobilisation of financial resources not only came from incumbents. Investments were also drawn from international investors in RETs, such as Good Energies.

However, in the expansion and downturn phase firm respondents do report mobilisation of both financial and human capital as a critical factor for lack of industry establishment in Norway (Tuv 2012, Enger 2011). REC for instance state that locating production in Singapore has to do with the availability of skilled personnel, in particular from pooled labour markets due to synergies with semiconductor industries. In addition respondents indicated that operating in financial markets abroad often is more beneficial than domestic, and also play a critical factor when it comes to relocating production facilities. A consequence of moving production to Singapore is that a larger extent of R&D activities are located close to production facilities (Enger 2011), which in turn entails reduction of R&D activities in Norway. Resource mobilization hence in turn may have effects on functional dynamics, such as knowledge development and legitimacy, as well as on structural issues such as organization, network constellations and domestic firm size and activities.

Similarly Innotech Solar on the other hand established production in Germany much due to investments support, where 50% of factory investments were supported. In addition, given their business model related to recycling of off-spec cells, proximity to suppliers and partners was reported as important (Tuv 2012).

The reduction of activities in Norway has numerous consequences, and is both symptomatic to system performance as well as having potential impacts on its future performance given that a range of large industrial production capacities are closing down and moving abroad. It is also conceivable that resource mobilisation becomes more challenging in the growth phase because firm and plant sizes are increasing.

Summing up the formation phase in particular was characterised by a heavy drawing of both financial and human resources from the existing regime, which allowed the rapid growth and further diversification well into during the expansion period.

5.2.4 Entrepreneurial experimentation

A TIS will develop given that there exists entrepreneurial experimentation (Bergek et al 2008). It relates to the functions above in the sense that new entrants may experiment with various technologies and production techniques. Moreover it relates to the development of knowledge in the sense that entrepreneurial experimentation entails using knowledge (Carlsson and Stankiewicz 1991). Such processes are however inherently uncertain but do contribute to learning processes associated with practical application of various sorts of knowledge. Uncertainty is related to high risk both in economical and technological terms (Bergek et al 2010).

Uncertainty was for instance reduced during the establishment of Scanwafer by how supply contracts were signed before manufacturing commenced. This particular move also secured the mobilisation of financial resources from public agencies and banks.

Knowledge accumulated through this function may be more practical and characterised by know-how and know-who types than what is characteristic of the first function presented. Whilst this function was highly present in early phase development of solar PV, the picture differs in the growth and decline phase. Firms such as REC and Innotech Solar choose to locate production in other countries due to a perception of better overall frameworks for industry establishment.

It must however be argued that, both wafer and raw-material experiments were strongly pronounced during the growth phase with a number of new processes developed in addition to a number of new entrants bringing with them new knowledge into the system. In particular the long-term development of new processes for silicon production were, as argued above, formed on the basis of combinations of many different knowledge forms. The particular combinations of science and experience based knowledge formed an important foundation on the long-term to develop new processes having impacts on the overall PV TIS by influencing the strained raw-material situation.

At the time of entry (mid 1990s) Norwegian firms were solely focusing on a particular and dominant design (crystalline silicon wafers). Although perhaps being a safe bet, thin film designs did constitute a differing type of design, with differing types of processes (and at times raw-materials) (Andersson & Jacobsson 2000). Experimenting with the dominant type of technology at the time, did however contribute to reducing the technological risk. Experimentation therefore also relied on the intra-TIS search direction

5.2.5 Lacking domestic markets

The process of market formation is key to technology diffusion and inclusion of users, and hence to TIS growth (Bergek et al 2010). Markets are however under developed for most immature technologies (Rosenberg 1976), and their formation usually entails the help of institutional change (Bergek et al 2008). Moreover, new technologies often are not broadly adapted to their ultimate use given that they often are crude and inefficient at early phases (Rosenberg 1976).

Electricity supply in Norway, which by and large stems from renewable hydro-power contributes to weak local market formation. PV does not play a role in power generation in Norway. Nor does there seem to be a large future potential for local PV deployment given the current transition context.[19]

Markets important for formation of the PV TIS in Norway did however exist outside of national borders. In particular Japan and Germany were critical to market formation for the global PV TIS given the use of deployment policy.

5.2.6 The legitimacy challenge of PV in Norway

Creation and maintenance of *Legitimacy* is associated with social acceptance and compliance with existing institutions. Without legitimacy it is challenging to mobilize political support and gain impact in broader society (Bergek et al 2010). For the purpose of discussion of

[19] Norway introduced a joint tradable green certificate market together with Sweden in 2012, but given that this is a technology neutral tool, investments in PV are likely to be low.

legitimacy of new RETs in Norway we may distinguish between *outer* and *inner* levels of legitimacy.

Outer legitimacy is coupled to how new RETs are potential problem solvers in relation to broad societal problems and challenges such as energy security and climate change. *Inner* legitimacy is coupled gaining acceptance for the specific conditions that need to be changed, be awarded with acceptance and/or stimulated in order to include new technologies within the existing system of energy production. Under many circumstances it is legitimate to argue for reduction in fossil fuel usage, but vastly more complicated to argue for the specific measures that need to be taken in order to reach alternative goals, because these often are associated with high costs (amongst others in subsidising market formation). Effects of TIS formation such as industry emergence and job creation, is key to this inner level of legitimacy. Employment and industrial development may legitimise ventures related to renewable energy.

In Norway these dimensions of legitimacy are only partly fulfilled given that development of new RETs does not alleviate a grand societal problem on a domestic level, i.e. there are no immediate energy security challenges where new RETs such as PV can function as a problem solver. New RETs in general therefore do not offer the solution to a bigger societal challenge and thus have weak outer legitimacy in Norway. Factors affecting inner legitimacy are however in place, such as the ones associated with socio-economic impacts amongst others due to work creation. A solar PV system in Norway hence achieves legitimacy due to its performance as a job and industry creator, not as a climate change mitigator or contributing to national energy security in a direct sense. As a result, legitimacy of PV in Norway is coupled to the inner level and how it performs on an industrial level. It attains legitimacy on the basis of its commercial function.

Even though attaining inner legitimacy in part due to job creation, and in terms of supplying other transition countries with technology, this dimension does not feed back on a broader outer level of legitimacy in Norway. The lack of overall legitimacy on an outer level may however challenge long-term viability of new RETs in Norway because part of the critical foundation for engaging in RETs development is lacking.

The recent cutbacks and offshoring processes within the PV-industry have for instance not resulted in any political action to alleviate the situation. If there had existed broader legitimacy to include outer levels (i.e. if PV was more broadly embedded), it may possible to imagine increased debate and action related to the process of reduced activity in the domestic PV sector.

5.2.7 Summing up

In sum a range of the systemic functions were impacted upon by several external contexts in the shape of sectoral systems or regimes. There exist very strong links from existing systems to influence on the direction of search, entrepreneurial experimentation, knowledge development and diffusion and resource mobilisation. On top of that there are strong inter-sectoral links to the electronics industry.

At the same time the system building process to a large extent relied on bottom up processes. For instance the critical role that Elkem played in terms of long-term knowledge development in the associated field of metallurgy constituted an important arena for facilitating knowledge flows through weak ties (Granovetter 1973).

The diverse sets of knowledge bases and flows from related systemic contexts constituted an important driver for emergence of a PV TIS in Norway. This function in particular is strong within the Norwegian context, and it rests on the interplay with other structural and functional aspects. In structural terms, the existing metallurgical sector provided an important cradle for change, in particular due to how a range of networks to a heterogeneous set of actors globally was used to facilitate knowledge flows.

The dynamics in the downturn period does however indicate how the Norwegian industry struggles to compete with Chinese actors in particular. This in turn relates to how functions such as resource mobilisation, entrepreneurial experimentation and legitimacy are weakened as the performance of TIS in economic terms is diminishing. Lastly it is a question of whether knowledge development and its impact on entrepreneurial experimentation is strong enough compared to that in China. New dynamics such as new process innovations in monocrystalline wafer production or investments in solar parks internationally do however signal activities that may strengthen the TIS over time.

6 Conclusions

This paper has dealt with two interlinked questions in the analysis of energy transition in Norway. The first concerns how transition contexts – existing regimes – play a role in transition dynamics and formation of new technological innovation systems – i.e. the dynamics between what exists and what emerges. In other words this question relates to which role regimes and processes of path dependence play for the emergence of new technologies. The second question related to how regime dynamics and the formation of new TISs depended on the exploration and exploitation of diverse systemic contexts, i.e. on inter-systemic dynamics and interaction with external contexts – other systems.

The purpose of this analysis was twofold. Firstly it relates both to gaining understanding of previously under investigated phenomena of endogenous regime transformation and inter-systemic dynamics within the literatures on transitions and technological innovation systems. The second purpose was to analyse and discuss processes of energy transition in Norway, and to analyse bottom-up driven processes of change.

This paper has shown how actors within the existing process industry were central in long-term innovation efforts that resulted in building a PV TIS in Norway. Norwegian actors, primarily with origins in the traditional metallurgical industry and related research environments coupled themselves to a rapidly growing solar energy industry. This was portrayed as a path dependent process which has its origins in production of lower grade silicon, then moved into production of silicon wafers and in turn also moved in to production of higher grade silicon for use in solar cells.

There are several conclusions that can be drawn from the analysis of formation of a system for PV in Norway. Firstly, the regime played an important role in several aspects of system formation, and may therefore be viewed as dynamic in the sense that processes of endogenous change came about. This relates to how the existing regime impacted on processes underlying system building such as knowledge development, influence on the direction of search and resource mobilisation. This has implications for how we can think about regime context, not only as constraining but also as dynamic. This was linked to the dynamics of long-term search processes within the traditional industry, in particular with regards to generation of knowledge bases that were instrumental in facilitating transformation to production of PV technology. In essence this was about making silicon cleaner in cheaper ways. But the search process on the one hand and the established industrial production enabled wide spun international networks in which actors that were linked to the old regime were embedded.

This leads us to the second point, which relates to how actors, networks, infrastructures and knowledge bases associated with the incumbent regime enabled a shift in trajectory. This regime change was in part facilitated through the strong networks built by actors linked to the existing regime, which in turn allowed the generation of knowledge flows from other systemic context to form a system for solar energy in Norway.

The overall learning process of attaining this however implied learning and relating to other sectors and industries, which proved important for subsequent diversification processes. Actors linked to the existing technological regime were active in exploring a diverse set of industries and sectors, and in turn exploited networks and distributed knowledge bases to enable build up industrial capacity to supply PV technology. Given that the processes of change were taking place within an embedded regime, it provided order and structure to the activities and choices made during the process of diversification. In particular we can recognise this in relation to the focus on developing a specialised supply of raw materials and in the overall downstream orientation set within the Norwegian national context.

It is these types of process that make it important to underline dynamics associated with what exists in relation to transition processes and the emergence of new technologies. The implications of analysing the emergence of a PV TIS in the face of existing regimes is that we not only can think about existing regimes as rigid structures constraining change, but also as contributing to the emergence of transition technologies. Hence we may identify the regime as a locus of change in the emergence of a PV industry in Norway. We may also think about them as enabling structures if allowed to diversify into associated trajectories. This in turn, as the analysis shows, relies on affinities in terms of actors, networks and knowledge bases that can be important in facilitating inter-systemic dynamics and thus be part of the dynamics of emergent innovation systems for transition technologies. The point about the role of existing regime in energy transition is critically important because it underlines that their structuring role in transition technologies is important also for dynamics of emergent transition technologies.

The emergence of a PV TIS in Norway in turn may be argued to have added a new layer in the global PV TIS. In particular this goes for the role of Norwegian actors in developing new processes for silicon production. Elkem, REC and other firms have established and implemented new production methods for silicon refining. Silicon access and cost for a long time constituted a key bottleneck for growth of the PV TIS globally. Thus the entering of Norwegian firms with origins in the silicon industries brought in a new and important knowledge base in the global system for PV. This knowledge manifested in new production processes affected dynamics along the value chain and for the TIS for PV as a whole in terms of contributing to raw-material access. Adding this structural element and new dimension to the global PV TIS may in turn be argued to be an important contribution to overall improvements for solar PV because it enabled a new supply of raw materials, based on new types of processes with impact on overall costs of production.

Norwegian actors succeeded in creating new processes that stood out in a global context. However as the system grew, firms and production facilities became larger it became increasingly obvious that some perceived frameworks abroad as more favourable for large-scale ventures and investments. It thus may seem that the development in the expansion and the downturn phases, in particular that of moving production abroad is related to both weaknesses in terms of resource mobilization locally, but also in term in overall institutional frameworks. Scale of production activities thus may seem as a factor contributing to these dynamics.

The process of diversification in the embedded regime implied the shift to a new industrial context – a shift to a new system that was in its formative stage and that was characterised by differing dynamics. Pace of change, uncertainty and the heterogeneity in design space was much bigger than in the old regime, where change occurred more in line with an established trajectory of incremental improvement. The shift to a new industrial context was however also one associated with different types of dynamics, in particular the fierce competition by Chinese actors and a rapid drop in PV prices.

A withstanding question is whether this was a fruitful transition strategy, and whether it has left Norway with a transition path for the future? Ultimately the story of PV transition, given its recent downturn, underlines that a largely bottom-up driven transition is challenged by the lack of transition strategies, visions and expectations, i.e. amongst others a deeper public sector involvement. If we link this to the role that the PV TIS plays in Norway it is clear that it does not play a role as a distinctive problem solver in terms of broad legitimacy coupled to climate change or energy security. It rather attained legitimacy on its economic merits alone. As these were fading in the down-phase, this affected the overall TIS. We can link this to how the TIS emerged in a bottom-up fashion in the absence of a clearly defined transition problem and strategy. The PV TIS was not deeply embedded in any such visions, nor did it form a part of a larger political strategy in the face of the grand challenge. Solar PV thus became an industrial strategy rather than a publicly orchestrated transition strategy. One key implication of the analysis of regime change through bottom up processes is also that the absence of top down drivers problematizes transition processes. Even though strong knowledge bases were established over time also within the field of solar PV, these by themselves were insufficient for the system to remain strong in a period of global unrest in the PV industry.

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165. The discourse and practice of transitions in global governance. An exploration of the international transition towards sustainable materials management

THIS IS A DRAFT—COMMENTS ARE WELCOME

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Transitions as a new concept in global governance

Since a number of years, 'transitions' have become a new buzzword in international politics. The concept refers to a strand of thinking that advocates fundamental changes in the main societal systems (food, mobility, housing, energy, etc.) in order to overcome society's persistent problems, such as climate change or resource scarcity. The concept is explicitly linked to the overall goal of sustainable development, and can be considered as a new way of thinking in sustainability science (Dedeurwaerdere 2013). Transitions thinking assumes that persistent problems, as they are rooted in our prevailing modes of production and consumption, can only be overcome when deep innovations are realized in societal systems ('system innovations'), by means of profound changes in dominant structures, practices, technologies, policies, lifestyles, etc. (Kemp and Rotmans 2005). After the concept of transitions was developed in the Netherlands in the context of the 4th National Environmental Policy Plan (Ministerie van VROM 2001), it has mostly been applied to national or sub-national processes experimenting with system innovation. But recently, the transitions discourse is permeating international policy documents too, from UNEP's green economy and the outcome of Rio+20, to EU Council Conclusions and the recent 2050 roadmaps by the European Commission (Council of the European Union 2009; EC 2011e; 2011f; UNCSD 2012; UNEP 2011).

It remains an open question why the international community openly and voluntarily embraces a concept that advocates such a fundamental shift in our way of life. Moreover, the true meaning of the phenomenon is still unknown. Is it just a change of terminology while business-as-usual continues, or do the words have a deeper impact? This paper explores the latter question. We are interested in analyzing whether concrete practices are attached to the international transitions discourse. Therefore, we conduct an exploratory case study analysis, looking at the discourse on sustainability transitions on the one hand, and at concrete principles, goals and instruments that follow from it on the other hand. In our analysis of global governance initiatives, we want to help broaden the academic transitions community's understanding of the importance of current international dynamics, as those are not yet systematically analyzed in transition studies (see also Happaerts and Bruyninckx 2012).

Conceptual and theoretical background of sustainability transitions

The concept of transitions emerged as a new solution to the problems of sustainable development. In the theoretical literature on transitions, those problems are said to be 'persistent', meaning that they are complex (e.g. because they involve multiple actors at different levels, each with their own perspective), uncertain (e.g. with regard to underlying mechanisms and future development), interdependent, deeply embedded in societal structures, and for those reasons difficult to manage or steer (Loorbach 2007).[1] Examples are climate change, the scarcity of certain energy sources or materials, housing and alimentation needs of a growing world population, etc. Because of their specific characteristics, persistent problems will not be solved by regular or short-term policy-making, incremental institutionalism or market mechanisms (Frantzeskaki and Loorbach 2008). As they are rooted in existing structures, they require a fundamental change in dominant institutions, policies, values, practices, lifestyles, etc. Those fundamental changes are called *transitions* (or *sustainability transitions* when their fundamental goal to achieve sustainable development is underlined). A significant part of the literature frames transitions in the context of socio-technical systems. Those are the systems that fulfil societal needs (such as feeding and sheltering people, moving around goods and persons, caring for people, etc.). They consist of three main components. The *structure* is the material infrastructure, the technologies, the different kinds of institutions and the associated economic reality of a socio-technical system. A system's *culture* contains the images, values and paradigms that are dominant. And the *practices* denote the 'normal' behaviour and routines within a system (Rotmans and Loorbach 2010). To achieve a transition, systemic changes or a *system innovation* is needed.

Transition theory refers to a bulk of literature that studies sustainability transitions from a range of different perspectives. A two-fold distinction can be made between those scholars that describe and explain historic transitions (e.g. from horse-and-carriage to automobiles) and those that analyze ongoing or future transitions and predict how they can be influenced (Paredis 2011). The community is assembled in the Sustainability Transitions Research Network (STRN 2010). While the diversity between scholars' interests is wide, a few concepts and heuristics unite the transitions community. The most common conceptual framework is the multi-level perspective (MLP), as initially developed by Rip and Kemp (1998) and refined by further research. The MLP is a heuristic tool that allows the analysis of changes within socio-technical systems. Research using the MLP has demonstrated that

[1] The characterization of persistent problems bears strong similarities with the 'wicked problems' defined in the policy literature (Rittel and Webber 1973), but it adds the specific perspective of sustainable development and the different layers of complexity that distinguish that policy issue from others (cf Lafferty 2004: 12).

transitions are the result of the interaction (or ‘co-evolution’) of phenomena taking place at three levels: the *landscape* (the exogenous societal and material environment that encompasses social, political and economic values and trends, shocks, etc.), the *regime* (the dominant setting of the socio-technical system, containing elements of technology, industry, markets, consumer preferences, science, culture and policy) and the level of *niches* (where new rules, technologies, behaviours… are developed that deviate from the regime) (Geels 2011; Geels and Schot 2010). Developments at the landscape level can put pressure on the regime and trigger innovations in niches, which ultimately cause the regime to adjust. But many other patterns of change (or inertia) are envisaged (Geels and Schot 2007).

Another common heuristic is the multi-phase trajectory, which represents transitions as an idealized S-curve with four consecutive phases: *predevelopment* (in which only minor changes occur or are prepared), *take-off* (where the change process gains momentum), *acceleration* (in which the change becomes structural and visible) and *stabilization* (where a new dynamic equilibrium is reached) (Rotmans and Loorbach 2010: 126). But not all initiated transitions end in a new dynamic equilibrium, other outcomes are possible too. Authors describe the risks of a *lock-in* (when attention is paid only to making existing structures more efficient, rather than changing them), a *backlash* (when the exclusive focus on one part of the solution causes unexpected side-effects) or a *system breakdown* (when no fundamental changes are initiated and the persistent problems eventually cause the socio-technical system to collapse) (van der Brugge and de Haan 2005; van der Brugge and Rotmans 2007: 254-256).

Within the research strand that focuses on how sustainability transitions can be governed or steered, models and strategies have been developed to operationalize transitions as a mode of governance. The most well-known model is Transition Management (TM), developed by a group of Dutch scholars (Kemp et al. 2007; Loorbach 2007; Rotmans and Loorbach 2009). TM prescribes a number of phases and instruments (e.g. a transition arena) that can be used by a group of frontrunners at the niche level and change-inclined regime players to formulate a joint long-term vision and to support short-term experiments that can help to reach that vision along multiple alternative ‘transition paths’. The TM model has been applied in a number of processes in the Netherlands, after the publication of the 4th National Environmental Policy Plan, and is now supported on a larger scale by the government of the Flemish region in Belgium (Vlaamse Overheid 2011; Vlaamse Regering 2011). Many scholars, however, criticize the model or the way it has been applied, for instance for its seemingly naïve idea about the ability to predict, control or govern system innovations (Shove and Walker 2007) or its lack of attention for political dynamics (Meadowcroft 2009).

The persistent problems of sustainable development are manifested on an essentially transnational scale, and the systemic changes that are needed to overcome them are thus international challenges. Moreover, if we study socio-technical systems, we need to take account of the increasing internationalization of economic structures, regulatory systems and technological development

(Meadowcroft 2005: 490-491). However, while the essential level of analysis of transition theory is thus transnational, most applications of transition theory adopt a national or sub-national level of observation (cf Raven et al. 2012). The transition literature has a built-in tendency to focus on bottom-up dynamics, on local experiments or on processes taking place within economic or technological niches, which can be referred to as a 'bottom-up bias' (Jørgensen 2012: 999; Lauridsen and Jørgensen 2010: 487). The theory has only sporadically been applied with an international level of observation (e.g. Lauridsen and Jørgensen 2010; Nilsson 2012; van der Brugge and Rotmans 2007). When it has, international developments and steering efforts are treated inconsistently, although the theory's main heuristics such as the MLP can be applied for the study of international dynamics and steering processes (see Happaerts and Bruyninckx 2012).

An exploratory case study

This paper wants to contribute to a more systematic analysis of transitions at the international level. While we demonstrated above from a theoretical point of view that transitions are inherently international, it is also observed that more and more international steering initiatives or policy strategies are adopting a discourse on transitions. We propose an exploratory case study of an international governance initiative, to analyze that discourse in more detail, and to verify whether it is also translated into governance practices.

The first part of the analysis deals with the discourse of the case. We want to analyze in which context and under which conditions the concept of transitions is used, and search for uses of other terms that are characteristic of the theory. In addition, we take a look at the broader policy framing of transitions in the context of the policy initiative or governance strategy at hand. *Policy framing* refers to the process of interpreting a concept and of giving meaning to a problem. The study of framing can offer some insights into why this specific concept is embraced by an international organization. It also serves the analysis of the problem for which the transition is advanced as a solution, and of what kind of a solution it is presented. Policy framing involves the use of available knowledge and information in order to select, name, emphasize or organize certain aspects of a policy problem (Daviter 2007: 654; Schön and Rein 1994: 26; Ward et al. 2004: 291-292). According to Schön and Rein (1994: 32), it takes the form of 'problem-setting stories', which are told with two aims in mind: to persuade others in policy debates, and to concretely shape the policies that are designed. The importance of policy framing cannot be underestimated. The particular way in which a policy problem is framed, has important consequences for the solutions that can be chosen for it and can already imply who will be responsible for that solution (Dovers 1995: 94; Hajer and Versteeg 2005: 178; Peters and Hoornbeek 2005: 82, 85; Rochefort and Cobb 1994: 4). It thus limits the policy choices that actors can make (Mazey and Richardson 1997: 112). Harrison (2000: 2) underlines that the selection of a certain framing involves subjectivity on the part of political actors, and that it reflects their own political ideology or preferred solution.

After having studied the discourse, we turn our attention to concrete practices that are proposed by the policy initiatives. We envisage that the transitions discourse can be used to advance specific principles, goals or instruments. We will look for principles that explicitly defend ideas or values related to sustainability transitions or systems thinking, either regarding the content of the initiatives or regarding the governance process (e.g. adopting a long-term perspective, a systemic view or a participatory approach). We then assess whether the transitions discourse is connected to any proposed goals or if the other policy goals (those not explicitly connected to the transitions discourse) are in line with transitions thinking. Finally, we conduct the same analysis for the proposed policy instruments.

For our case study, we focus on the field of materials and natural resources.[2] There are three reasons why that focus is justified in this analysis. First, materials are central to the major global production and consumption patterns, which are at the core of many persistent problems of sustainability. As the extraction, production and consumption of materials are necessary for the provision of buildings, transport, energy and food, materials have a vital link to the main socio-technical systems. Second, the debate on sustainable materials management is linked to the geopolitics of natural resources. That is a domain in which public intervention is expanding, at the expense of global free market mechanisms (HCSS 2011). For that reason it is highly pertinent to look at initiatives intended to govern the transition towards a sustainable materials system at the international level. The materials system in itself is, of course, inherently global in scope. In the primary production of materials, different resources from various parts of the world are brought together, while the associated surplus value creation is transboundary and involves transnational corporations that operate within different national and supranational rule systems. Consumption patterns of materials are globalized and generate several transnational waste flows. The materials system also engenders a number of externalities that have a global character (e.g. long-term or short-term environmental impacts and chronic and acute health hazards). A third reason why this paper focuses on materials, is our observation that the materials system increasingly becomes the object of initiatives aimed at steering transition processes. For instance, in Flanders—labelled the first 'testing ground' of TM outside of the Netherlands (Paredis 2008)—the materials system was one of the first areas in which a transition arena was set up, and in which progress has been most visible. Also at the international level, the discourse on sustainable materials management is moving toward the language of

[2] *Materials* can be defined as "all tangible materials extracted from the biosphere or technosphere as resource for human use" (SuMMa 2011: 6). For the European Commission (2011d: 2), *natural resources* entail not only raw materials (minerals, metals and fuels), but also food, air, soil, water, biomass and ecosystems.

transitions. That holds true for a number of EU policies and for several initiatives taken by the OECD (and to a lesser extent the UN).[3]

In this paper a single exploratory case study at the level of the EU is proposed. The EU has been taking action in the area of sustainable materials management since the beginning of the 2000s, mainly from an environmental policy point of view (EC 2005). After the global financial and economic crisis broke out in 2007, EU efforts accelerated and became more focused on the governance of raw materials (EC 2008). The Roadmap to a Resource Efficient Europe (EC 2011f), presented by the Commission in September 2011, is now the cornerstone of the EU's materials and resource policy, and the number one priority of the EU's environmental policy (see Potočnik 2012). The Roadmap directly follows from the Europe 2020 strategy, which defines seven flagship initiatives that need to catalyze progress within a number of priority areas. Resource efficiency is one of them.[4] After the Commission's general communication on the flagship initiative (EC 2011d), an interdepartmental task force led by DG Environment drafted the Roadmap. It has the particularity of supplementing the goals and targets of the Europe 2020 strategy with a long-term vision aimed at 2050, thus attempting to stimulate a transition towards a resource-efficient society. The Roadmap and the initiatives that are associated with it form the case study of this paper. It is our aim to complement the exploratory analysis in a later stage with other case studies at the level of the OECD and the UN.

The main sources used in the analysis are the Roadmap itself (EC 2011f) and the accompanying documents by the European Commission (EC 2010a, 2010b, 2011a; 2011b, 2011d, 2012b, 2012c). We also refer, where relevant, to the positions of the Council and the European Parliament with regard to resource efficiency (Council of the EU 2011; European Parliament 2011, 2012). In addition to a thorough document analysis, we draw insights from two interviews with Flemish government officials (June 2012), from two interviews with officials from the European Commission's DG Environment (November-December 2012) and from non-participant observation at two informal workshops of EU Member States on resource efficiency (April 2012, Brussels and November 2012, Berlin).

[3] This research is funded by the Flemish government in the framework of the Policy Research Centre on Sustainable Materials Management (SuMMa). The goal of the project is to map and analyze the global and European context of the transition towards sustainable materials management.

[4] Europe 2020 is the successor of the Lisbon strategy and the EU's high-level policy framework to achieve "smart, sustainable and inclusive growth" in 2020 (EC 2010a). The flagship initiatives are a Digital Agenda for Europe, Innovation Union, Youth on the Move, Resource Efficient Europe, an Industrial Policy for the Globalisation Era, an Agenda for New Skills and Jobs, and the European Platform against Poverty (EC 2010a: 5-6). Resource Efficient Europe and an Industrial Policy for the Globalisation Era are the flagship initiatives of the 'sustainable growth' dimension.

The discourse and framing of the European transition towards resource efficiency

An intentional discourse on transitions and system innovation

The EU's resource efficiency policy is a good example of the popularity of a new transitions discourse in international policy documents. The three main European institutions frequently use the word 'transition' in the context of the Roadmap (Council of the EU 2011; EC 2010b; 2011d, 2011f; European Parliament 2012). The word appears most regularly in the Commission working document that accompanies the Roadmap, where it systematically structures the analysis (EC 2011a).[5] The concept usually stands alone, but it also appears in combination with "resource efficiency", "a resource-efficient economy", "a resource-efficient Europe" or "a resource-efficient society". Furthermore, the policy discourse mentions the transition towards "a green economy" (Council of the EU 2011: 4; EC 2011f: 3, 8, 22), "a low-carbon economy" (EC 2011a: 22, 2011f: 8, 14) or "a low-carbon Europe" (EC 2011a: 11).[6] The Commission defines a transition as "a fundamental transformation within a generation – in energy, industry, agriculture, fisheries and transport systems, and in producer and consumer behaviour" (EC 2011f: 2), and the terms 'transition' and 'transformation' are used interchangeably in the policy discourse (e.g. EC 2011a: 24, 2011f: 4).[7]

'Transition' is not the only word that permeates the EU's resource efficiency discourse. The Commission makes a clear reference to the concept of socio-technical systems, when it calls for "a significant *transition* in energy, industrial, agricultural and transport *systems*" (EC 2011d: 3, own emphasis). The Council refers to system innovation, when it states that the shift towards resource efficiency "will require, in addition to technological innovation, *innovation at the level of our socio-economic system*, i.e. new governance models, new business and education models, new consumption patterns, and lifestyles geared towards the sustainable management of resources" (Council of the EU 2011: 5, own emphasis). The awareness of the other possible outcomes of a transition trajectory is also manifested in the discourse. The Commission adopts the explicit wording of "lock-ins" of socio-technical systems when it refers to market distortions, to our technological and knowledge system, to prevailing institutions or to dominant production and consumption patterns (EC 2011a: 20-23, 2011b: 14-16, 18, 28, 34, 54, 56, 2011f: 4, 10). In a single instance, the Commission warns against the risk of "systemic collapse" when current resource use persists (EC 2011a: 6).

In the spirit of transitions thinking, it is not unimportant that the Roadmap systematically stresses its long-term perspective and that it will take a generation to achieve the transition (EC 2011f: 2).

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[5] For instance, some of its subtitles are "Why is economic transition needed?", "Costs and benefits of the transition to a resource-efficient Europe", "Potential costs around transitions", "Policy objectives in the transition to a resource-efficient, low-carbon economy" and "Governance change for facilitating transition" (EC 2011a: 2).

[6] A similar transitions discourse is also found in other EU long-term strategy documents, most notably DG Climate Action's Roadmap for moving to a competitive low carbon economy in 2050 (EC 2011e).

[7] The term 'shift' appears occasionally (EC 2011a: 9, 2011d: 3). While they are used interchangeably by the European institutions, some transition scholars emphasize conceptual differences between 'transition' and 'transformation' (Meadowcroft 2005: 484).

While the adoption of long-term policy strategies oriented towards 2050 is a recent trend in the European Commission (2011c, 2011e, 2011g), the Roadmap is the only one of Europe 2020's flagship initiatives that genuinely looks beyond 2020. Another manifestation of the transition discourse is the explicit reference to TM. A working document states that the Roadmap is about the "choices on […] how to best manage transition" (EC 2011a: 1) and it advances the example of the "Dutch government['s] […] 'transition management' as national policy" (EC 2011a: 28). The Roadmap itself is less explicit, but it expresses the ambition to "[p]repar[e] that transformation in a timely, predictable and controlled manner" (EC 2011f: 2). Some of the specific TM instruments are mentioned as well. 'Transition paths' surface in one document (EC 2010b) and one of the Roadmap's most prominent instruments is modelled after the Dutch transition arenas (see below).

Although the Commission defines a transition as a fundamental transformation, and although interviewees stress the Commission's awareness that incremental changes are not enough for a transition, it is unclear from the discourse itself how fundamental the proposed changes are considered to be, as Commission documents have the tendency to be cautious and avoid radical wording. That is illustrated by the references to the concept of decoupling, an important principle of the Roadmap. While the goal of decoupling economic growth from resource use is frequently mentioned (EC 2011d: 5, 2011f: 2; European Parliament 2012: §7), it is unclear whether the aim is to achieve *absolute* decoupling (i.e. economic growth continues while resource use decreases) rather than *relative* decoupling (i.e. resource use continues to increase, but less intensively than economic growth). The Commission only mentions absolute decoupling in a staff working document that contains background analyses and trends on resource use (see also EC 2010b; 2011b: 96), but we learnt from interviews that a lack of consensus within the Commission prevents the explicit promotion of absolute decoupling of resource use. Although it is never formally confirmed, the Commission's discourse on 'efficiency' and 'doing more with less' goes much more in the direction of relative decoupling. The Council of Environment Ministers is in that regard more ambitious than the Commission, when it calls for "*absolute* decoupling of growth from resource use *and negative environmental impacts*" (Council of the EU 2011: 6, own emphasis; see also Council of the EU 2012: 4, 6). The Council also emphasizes the decoupling of environmental impacts, while the Commission in its more cautious wording mentions only resource use as such. The European Parliament in its turn stresses the "need to focus on both the efficiency *and effectiveness* of resource use" (European Parliament 2012: §10, own emphasis). More radical ideas, such as a focus on sufficiency instead of efficiency or effectiveness (cf Princen 2005), are not a part of the EU's discourse.

At this point, we can conclude from the analysis that the appearance of a discourse on transitions in the EU's resource efficiency policy is much more than the sporadic mention of the word 'transition'. The concept is frequently used, as well as some of transition theory's other core concepts. That points towards an obvious awareness of the conceptual and theoretical framework of sustainability transitions, and the deliberate attempt of the European Commission to position the EU's efforts for resource efficiency within that framework. Our interviewees confirm that some of those who wielded the pen of the Roadmap (including Dutch and Flemish EU officials) know the literature of transitions and TM very well and used it intentionally for the Roadmap.[8] They are conscious about the importance of such a discourse and indicate that they see it as an important strategy to create awareness and push for a sense of urgency and an idea that fundamental changes are necessary. However, although they are convinced that EU policy-makers are generally aware of the meaning of the concepts of transitions and system innovations, they doubt that everybody has the same idea about the exact system state that the EU should aim for.

An economic policy framing of resource efficiency

In the analysis of the policy framing, we first pay attention to how the problem of sustainable materials management or resource efficiency is framed, and second to how the proposed solution is interpreted and presented.

First of all, Commission officials stress that their efforts are about natural resources in a *systemic* sense, encompassing raw materials (metals, minerals and fuels), food, air, soil, water, biomass and ecosystems. They avoid the label 'sustainable materials management' (preferred by, for instance, the OECD), which they consider too narrow. In the policy framing of resource efficiency, the EU's resource problem is very clearly an economic one. Changing trends on a global scale indicate a rising demand for a number of materials, and different forms of scarcity follow from that. That is a very bad situation for the competitiveness of the EU, whose economy depends to a large extent on the import of commodities. While Europe has important stocks of certain metals or building materials, it is very dependent on the import of oil, gas, precious metals, certain minerals, rare earths, etc. The scarcity of resources causes volatile prices, which is the most frequently mentioned problem. While the price of natural resources systematically declined after the end of the Second World War, the Commission stresses that it has been rising sharply in recent years (EC 2011a: 3-4, 2011d: 2, 2011f: 2-3). Besides global economic trends, the Roadmap deals with market distortions or systemic construction errors within Europe. Those are situated in three domains. First, the EU addresses the problem of externalities (such as pollution or waste) that are not reflected in the prices of resources. As a consequence, signals of scarcity are not perceived, and unsustainable exploitation and inefficient consumption are promoted (EC 2011a: 20, 2011f: 2, 4-5, 9-11, 23). Second, the Roadmap denounces the exclusive orientation of financial markets towards short-term interests, whereas the long-term gains of resource efficiency are not sufficiently rewarded (EC 2011a: 19, 2011f: 20).[9] In a working document of the European Parliament, it is argued that this "vested interest focussed on short-term

[8] The interviewees also indicate that those same officials intended to integrate the discourse on transitions already in the 2005 Thematic Strategy on the Sustainable Use of Natural Resources (EC 2005), but that it was impossible at that time.

[9] While the speculation in natural resources and commodities is commonly perceived as a major problem with regard to the price setting of resources (PBL 2011: 23, 27, 34), speculation is not addressed by the Roadmap.

economic gains needs to be defied" (European Parliament 2011). Third, a related distortion is the unfamiliarity of investors with the returns of resource efficiency, which functions as an obstacle for sustainable investments (EC 2011f: 9, 12, 20). In its framing of resource efficiency as an economic problem, the Commission refers to several studies and uses many numerical data in order to underpin its arguments with a reliable scientific base.

Although the Roadmap is an initiative of DG Environment, environmental problems take a backseat in the economic policy framing. Only limited attention is given to the pressure of the EU's extensive resource use on ecosystems and to its contribution to climate change (EC 2011a: 4-6, 2011f: 2). The same goes for social and demographic changes (EC 2011a: 2). Moreover, when problems related to environment, energy or health are invoked, they are framed as economic problems and expressed in, for instance, the loss of working days (e.g. EC 2011f: 14). Another element of the problem framing is the fact that other actors on the international stage are taking steps towards resource efficiency and that it all fits in a global transition (EC 2011a: 9-10, 2011d: 8-9, 2011f: 3, 22). Finally, the transition towards resource efficiency is also presented as a policy problem, and explained as the result of policy failures and inconsistencies, e.g. inefficient subsidies (EC 2011a: 20-22; 2011f: 9-11; Potočnik 2011).

The solution to the resource problem is framed as an economic story as well. The EU sees for itself a significant role in what it calls "transforming the economy" (EC 2011f: 23). The Roadmap proposes a number of adjustments that can be made in the system's *policy* framework (of which the EU controls a significant part) in order to eliminate the distortions and construction errors of the *market* framework. The EU thus focuses on a narrow relation within the dominant regime of the socio-technical system of materials, as the Roadmap largely ignores other components such as consumers, science or technology. The solutions for a new policy framework mostly revolve around the principle of 'getting the prices right'. Policies must create economic opportunities, offer the right incentives for investments, reward innovation and resource efficiency, and ensure the security of supply. The way to do this is on the one hand by conducting policies that promote product redesign and increased reuse, recycling and substitution of materials, and on the other hand by improving the coherence among existing policies, which "shape our economy and our lifestyles" (EC 2011f: 2). An improved policy framework, in short, offers long-term certainty to businesses and investors about the future policy direction of Europe, which is aimed at resource efficiency.

The solution advanced by the Roadmap is presented as a blessing for the European economy. The multiple economic advantages of resource efficiency are systematically emphasized: it will lower the EU's import dependence and boost the competitiveness of its economy (EC 2011f: 4, 6, 8, 10-11, 19-20), it will be a source of growth, profit and jobs (EC 2011f: 2, 4-5, 8, 10, 20), it will offer opportunities for businesses to capitalize on the commercialization of their innovations and to use waste as a resource, and it will help consumers to save money (EC 2011f: 2, 4-6). With all those economic benefits, the Roadmap to a Resource Efficient Europe is actually presented as a guidebook out of the European economic crisis.

The Roadmap's solutions suggest a firm belief in the market's ability to steer itself, provided that policies offer the right incentives. The EU's confidence in the functioning of improved market mechanisms should not be surprising and can partly be explained by the fact that the strongest EU competences relate to the internal market. In several domains, the European Commission tends to invoke its competences with respect to the internal market as the legal basis of policy proposals (e.g. Pollack and Shaffer 2005: 331). Already during the recession of the late 1970s, the EU's environmental policies were framed as economic measures (Lenschow 2005: 307, 312). During public events in 2011, we heard Commission officials explain how the Roadmap can be seen as an attempt to 'resell' the EU's environmental and climate objectives as an economic agenda. It should be highlighted here that the Commission, an actor with its own preferences and interests, is known to use its right of initiative in EU policy-making to frame proposals as much as possible to its advantage (Hix and Høyland 2011: 212).

The conclusion with regard to the policy framing of the Roadmap is unequivocal. The strategy is led by DG Environment and it is explicitly presented as the 'environmental' flagship of Europe 2020 (see footnote 4). However, the EU's resource use is completely framed as an economic problem, and its answer, resource efficiency, is framed as an economic solution. Although that is not a new strategy, it deviates from the basic mission of the EU's environment policy, i.e. to protect and improve the environment, when environmental concerns take a back seat to the economic policy framing. Interviewees explain that the economic problem-setting should be considered as the Roadmap's greatest success, as it is probably the reason why it was accepted as one of the EU's central goals at such a high level (with its integration in Europe 2020). At a time when a global financial and economic crisis—revealed by, for instance, high commodity prices—coincides with escalating environmental crises, it is indeed a first that an environmental strategy is so broadly recognized as a core economic problem. The underlying argumentation that this is the best way to achieve progress in the EU's environmental policy, has yet to be proven.[10]

Principles of the resources transition

An analysis of the Roadmap shows that a number of principles that are rooted in transitions thinking are strongly embedded in the policy initiative. Those include a fundamental observation about the unsustainability of our current system, a systemic approach, a long-term approach and the new paradigm of a circular economy. A number of other principles give shape to the Roadmap—

[10] The European Parliament (2011: 5) suggests that a political battle must still be fought inside the Commission on the position of resource efficiency on the EU's political agenda.

decoupling, getting the prices right, monitoring and participation—but their elaboration appears focused on the optimization instead of on a fundamental innovation of the socio-technical system.

As a first fundamental principle, the Roadmap departs from the observation that our current patterns of resource use are unsustainable (EC 2011f: 2), thus implying that business-as-usual is not an option. The Roadmap then advances a systemic approach to suggest solutions to alter the EU's resource use. It does so by consistently coupling resource efficiency to other major domains and European policies (e.g. energy, agriculture, industry, transport). Even though concrete measures in those domains are not always elaborated, the Roadmap proposes to take land use impacts into account in all policies, to move from energy efficient policies (e.g. for buildings) to resource efficient policies, and to integrate resource efficiency into the European Semester, among other examples. Besides its systemic approach, the long-term approach embedded in the Roadmap also fits well with a transitions perspective. The strategy is built on the idea that current practices must be aligned with the long-term gains of sustainable resource use, even though that implies short-term investments and costs. The most visible expression is the formulation of the vision for 2050. As mentioned above, Resource Efficient Europe is the only flagship initiative of Europe 2020 that explicitly adopts a long-term perspective, but it joins a number of other EU 'roadmaps' that embark on this new trend (EC 2011c; 2011e, 2011g). The long-term perspective is frequently invoked as an approach that clashes with normal market practices (EC 2011f: 6, 20). A final principle in line with transitions thinking that we want to highlight here, is the idea of a circular economy. That concept is becoming a new buzzword in the governance of resources (e.g. Ellen MacArthur Foundation 2012) and is increasingly used by the EU to frame the transition towards sustainable materials management (EC 2012a). The principle is used in the Roadmap to advance certain ideas and approaches that suggest a move towards a new materials system based on closed material loops, e.g. turning waste into a resource or adopting lifecycle approaches, but its elaboration remains relatively vague.

The Roadmap rests on four other principles that suggest a change in the EU's resource use, but which appear to avoid rather than support a fundamental system innovation. The first one is decoupling, which we already mentioned before. As stated above, the principle is interpreted as relative decoupling, meaning that economic growth remains the priority and that effects on resource use are a secondary issue. The second principle is 'getting the prices right', the dominant image of the economic policy framing of the Roadmap (see above). It is linked to the idea that consumers will make more resource-efficient choices if they are properly informed and if taxes and product prices reflect the real environmental costs and the true value of natural capital. The two principles of decoupling and correct prices are oriented towards optimizing the current system of resource use, which according to the EU is characterized by market failures, rather than towards a real innovation of that system. It goes against one of the fundamentals of transitions thinking, which states that market mechanisms (even if they function optimally) can never offer a satisfactory solution to persistent problems (Frantzeskaki and Loorbach 2008). Another principle that is strongly present in the Roadmap, is monitoring.

Transition theory attaches much importance to evaluation and monitoring, as it drives the reflexive learning processes that are essential for achieving transitions (Bussels et al. 2013). The Roadmap, however, focuses exclusively on the development of indicators to measure the EU's progress towards resource productivity, and neglects more reflexive forms of learning and monitoring. A similar assessment is made with regard to participation, a final principle of the Roadmap. While the EU strongly invests in the involvement of all relevant stakeholders (Member States, business, civil society, etc.), that participation is only invoked for the development of the resource efficiency indicators, a very narrow aspect of the governance of the initiative.

In conclusion, a number of principles suggest that the EU makes an attempt at intervening in the culture of the socio-technical system, i.e. the prevailing images, values and paradigms of resource use in the EU. The point of depart that the current system is unsustainable, the emphasis on a long-term, systemic approach and the new paradigm of a circular economy are clearly intended to achieve a necessary "shift in mindset" (EC 2011f: 20). However, the elaboration of some other principles, such as decoupling and the internalization of external costs, shows that the Roadmap tends to aim at an optimization of the current system, i.e. making current resource use much more efficient, rather than striving for a fundamental innovation of that system. In the perspective of transition theory, although some of the Roadmap's principles can be regarded as fundamentally new in comparison to current European policies and practices, they thus bear the risk of investing in a lock-in of the current system.

Long-term and short-term goals: baby steps to initiate a transition?

The Roadmap to a Resource Efficient Europe is a Commission proposal. As such, it logically sets out policy goals that are aimed at shaping EU policies in the years to come. In the Roadmap, goals are formulated at three levels: long-term (2050), medium-term (2020) and short-term. In the perspective of common governance models for sustainability transitions, it can be considered as a 'transition agenda' (Loorbach 2007). That agenda departs from the long-term vision, which reads as follows:

> "By 2050 the EU's economy has grown in a way that respects resource constraints and planetary boundaries, thus contributing to global economic transformation. Our economy is competitive, inclusive and provides a high standard of living with much lower environmental impacts. All resources are sustainably managed, from raw materials to energy, water, air, land and soil. Climate change milestones have been reached, while biodiversity and the ecosystem services it underpins have been protected, valued and substantially restored" (EC 2011f: 3).

While it is relatively vague and certainly not ambitious enough for some, the vision contains the EU's long-term goals with regard to resource efficiency in a condensed form. Its main merit is that it exists, and thus integrates a long-term perspective into the policy process.

The vision is translated into eighteen 'milestones' or mid-term goals to be reached by 2020. The milestones relate to the 'key issues' and governance aspects identified by the Roadmap.[11] Some correspond to 'hard goals' (e.g. environmentally harmful subsidies are phased out in 2020) or figured targets (e.g. water abstraction stays under 20% of available resources), while others remain very vague (e.g. transport will use less and cleaner energy). Interviewees reveal that most milestones were formulated according to different resources, rather than sectors, to avoid creating the perception that DG Environment would encroach upon other domains (e.g. agriculture, fisheries, transport, construction, etc.). Nevertheless, the Commission found that the milestones were the object of the bulk of the criticism that the Roadmap received by Member States and other actors, as they were too vague for some or too ambitious for others. The Commission is now in the process of formulating more specific targets for the milestones, in consultation with Member States.

Short-term actions are formulated for each milestone. Those actions, around 100 in total, are proposals of what either the Commission or the Member States (or a combination of the two) will or should do between 2012 and 2020. About half of the actions involve the implementation, evaluation or (partial) improvement of existing policies, while only a fifth deals with new policy measures (the rest consisting of vague goals related to research or the promotion of certain issues). The Commission defends the inclusion of so many actions related to existing policies, arguing that many subsectors already have targets, and that the actions formulated by the Roadmap can help those targets to be reached, by exploiting synergies between subsystems (EC 2011a: 24). Interviews show that the formulation of the actions was even harder than the definition of the milestones, which is why they are most similar to incremental policy-making.

The analysis of the policy goals reveals that, following the strong discourse on transitions in the Roadmap, the long-term and systemic approach is translated into a long-term vision for a resource-efficient Europe and a number of strategic goals covering a wide array of fields important for resource use. However, the more concrete and immediate the policy goals become, the more they deviate from fundamental transformations and suggest an approach based on incrementalism and improved

[11] Those are: 'sustainable consumption and production' (two separate milestones), 'turning waste into a resource', 'supporting research and innovation', 'environmentally harmful subsidies and getting the prices right' (containing one milestone on subsidies and one on taxation), 'ecosystem services', 'biodiversity', 'water', 'air', 'land and soils', 'marine resources', 'addressing food', 'improving buildings', 'ensuring efficient mobility', 'new pathways to action on resource efficiency', 'supporting resource efficiency internationally' and 'improving the delivery of benefits from EU environmental measures'. One of the key issues, 'minerals and metals', does not have a milestone because the question is already tackled by the Raw Materials Initiative (EC 2011f: 13). In addition, the Roadmap does not include a section on energy—although that is definitely one of the sectors besides food, buildings and transport that has a high impact on resource use—because that is already covered by another Roadmap (see EC 2011c).

business-as-usual. The Roadmap thus proclaims a firm sense of urgency, but shows little willingness to make fundamental choices right away.

Market-based and information instruments and the European Resource Efficiency Platform

As a broad strategy proposed by the Commission, the Roadmap does not create radically new instruments. It does, however, lay out a spectrum of governance strategies that should be used to achieve a more resource-efficient Europe. Those strategies include addressing markets and prices, promoting new business models and production patterns, stimulating innovation, integrating lifecycle thinking, adequately informing consumers, boosting knowledge and information-sharing, and developing indicators.

Three types of instruments are particularly promoted. First, the Commission attributes a significant role to the instruments pertaining to the internal market and the EU's new competences with regard to 'economic governance'. Exactly those instruments give the EU the "sufficient scale of influence" needed for the transition (EC 2010b). For instance, the Commission wants to integrate resource efficiency objectives into the European Semester (EC 2011f: 11, 19, 21). Its preference to use market-based instruments is explained by the EU's strong competences with regard to the internal market (see above).

A second type of instruments are information instruments. That refers to the work on indicators, but also to the proposed measures with regard to product footprinting and other informational tools (e.g. EC 2011f: 7). Its preference for information instruments demonstrates that the Commission realizes that it is the best placed institution for the monitoring of the transition towards resource efficiency in the EU, and that it can partially influence the transition by developing indicators. The focus on indicators can also be explained by the common critique on the Lisbon Strategy, Europe 2020's predecessor, about the lack of concrete targets and indicators. This time, the Commission wants to actively monitor the progress of Europe 2020, and the indicators developed for resource efficiency will serve the monitoring of the 'sustainable growth' dimension (see footnote 4). Furthermore, some have stated before that working on indicators is popular because it is less threatening than actually intervening for change (Kemp et al. 2005: 21).

A third type of instruments is used to encourage the cooperation of specific stakeholders during the implementation (not formulation) of the Roadmap. Several of the short-term actions call for the establishment of platforms and partnerships on specific topics. The most prominent proposal is the launch of an "EU Resource Efficiency Transition Platform" (EC 2011f: 21). Interviewees explain that this is an explicit reference to the 'transition arenas' of the TM model. A Commission staff working paper mentions the example of the "transition platforms" that the Dutch government had used for its transition policy (EC 2011a: 28). The platform was formally established in June 2012, under the name

‘European Resource Efficiency Platform’. According to interviews, the choice was eventually made to give the platform a shorter name for communication purposes, and because the concept of ‘transition arenas’ is not well known in government circles apart from the Netherlands and Belgium. The European Resource Efficiency Platform brings together a number of Commissioners, MEPs, Environment Ministers, international organizations and representatives of different stakeholder groups (industry, labour unions, environmental groups and research) and it meets at least twice a year. It is meant as a high-level consultation group that should give guidance to the implementation measures of the Roadmap and monitor its progress (EC 2012c).

The Roadmap thus contains at least one instrument that is explicitly derived from transitions thinking. But in general, the Roadmap mostly relies on market-based instruments and on information instruments. Rather than developing new instruments, it refers to a significant degree to already existing policies and measures, thus supporting an incremental approach.

Conclusions

Transitions are a new concept in global governance. The exploratory case study of the Roadmap to a Resource Efficient Europe suggests that it did not permeate international policy discourse for no reason. For DG Environment, the discourse on transitions builds upon previous experience with environmental policy and is meant to take future policies one step further and to move towards a more fundamental transformation. That is also why the discourse goes further than the use of the word ‘transition’. The Roadmap is deeply embedded in transitions thinking, and the application of that framework is very intentional. But a discourse is more than the language that actors speak. We analyzed the policy framing of the Roadmap and concluded that both the problem and the solutions of resource efficiency are presented as economic issues. That contributed to the ‘success’ of the Roadmap (measured by its high-level political backing and its integration into Europe 2020). But another consequence is that the actions it proposed can only manoeuvre within existing economic frameworks and that the focus is on improving policies in order to eliminate market distortions. Therefore, the radical character of the Roadmap’s discourse is at the same time attenuated by its economic policy framing. The analysis furthermore shows that the momentum was ideal for the introduction of a discourse on transitions in this EU policy initiative. Several factors contributed to that: landscape trends with regard to resource use and commodity prices, the EU searching for ways out of the ‘eurocrisis’, an Environment Commissioner looking for another big story after handing over climate change to another Commissioner, and EU officials with a knowledge of transitions and TM in the right positions.

This paper also addressed the question whether the transitions discourse is translated into governance practices, operationalized as principles, goals and instruments. We conclude that the popularity of transitions within international organizations indeed goes further than the discourse. The Roadmap puts much emphasis on a number of principles that are directly related to transition theory and that will shape future policies. However, some other principles of the Roadmap reveal a tendency to be more cautious. The formulation of policy goals is also influenced by the transitions framework, especially with regard to the long-term dimension of the Roadmap. But as the goals become more concrete and short-term, the envisaged transformation becomes less and less fundamental. With regard to policy instruments, the Roadmap explicitly uses the example of TM to create a consultation platform, but it relies mostly on market-based and information instruments to stimulate the market to steer itself towards resource efficiency. The governance practices that are derived from transition theory thus show a very ambiguous approach towards incremental policy-making. On the one hand, a fundamental transition of socio-technical systems is promoted. On the other hand, incremental steps building on existing systems are the only option for the short term. The reason is that a more fundamental approach would have never been acceptable for other actors (also within the Commission). As a consequence, it is only natural that "transition-management-in-practice looks a bit more like policy-as-usual than would be recommended by transition-management-in-theory" (Meadowcroft 2009: 336). The question then becomes whether the Roadmap, while advocating a system innovation, is actually steering the EU towards a lock-in of its current resource use.

The goal of the paper was to contribute to a more systematic understanding of transitions discourses and practices at the international level and to move away from the literature's 'bottom-up bias', because transitions are inherently transnational and international organizations are increasingly embracing the concept. This question also relates to a broader debate on scale and geography in the transition literature, where important conceptual and theoretical challenges lie ahead (e.g. Coenen et al. 2012; Raven et al. 2012). Our conclusion is that some of the international efforts, notably in the EU, deserve more attention than they currently receive in the transitions community. Steering efforts such as the Roadmap to a Resource Efficient Europe should be taken into account in analyses of transitions in Europe, because EU institutions are key actors in most socio-technical regimes.

The empirical material analyzed in this paper shows that the uncharted territory of transitions is vast and offers many opportunities for further research. As our interest goes out to global governance, it is our aim to complement this analysis with other case studies at the level of the OECD and the UN, to gain a broader view. We also believe that transition theory will benefit from cross-pollination with theoretical frameworks within political sciences, such as policy analysis or EU studies, to contribute to a better developed understanding of the political aspects of sustainability transitions (Meadowcroft 2011).

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Lead markets for clean coal technologies

A case study for China, Germany, Japan and the USA

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Abstract:
Despite the high CO_2 emission intensity of fossil and especially coal fired energy production, these energy carriers will play an important role during the coming decades. The case study identifies the main technological trajectories concerning more efficient fossil fuel combustion and explores the potentials for lead markets for these technologies in China, Germany, Japan and the USA taking into account the different regulation schemes in these countries. We concentrate on technologies that have already left the demonstration phase. This is the case for supercritical (SC) and ultra-supercritical (USC) pulverized coal technologies that are already established.
The analysis shows that the typical pattern of a stable lead market only applies to a limited extent. In the 1960s and 1970s, the USA has established a lead market for SC und USC technologies. In the meanwhile, Japan has surpassed the United States, although it started as a typical lag market. Japan has caught up in terms of supply factors, China in terms of price, demand and regulation advantage.
This supports the hypothesis that - apart from the demand-oriented lead market model - push factors such as R&D activity play a strong role as well. The advantage of Japan mainly stems from its intensive R&D activities. It can also be observed that some other advantages – such as price and demand advantage – are shifting to China. China is practicing a leapfrogging strategy, and has already become a leader in the market segment of low and middle quality boilers, whereas Japan and Germany still dominate the world turbine market.
The conclusion is that lead markets may switch over time to markets with high growth rates, although first mover advantages exist for some market segments such as turbines. First movers have a strong technological expertise which is important in the catching up process of late followers, and they may even profit from the growth in lag countries by exporting and co-operation activities. Thus international technology cooperation is a beneficial process for all involved parties.

Keywords: Lead Markets, Coal Power plants, Energy Technology, Energy Policy

1 Introduction

Despite the high CO_2 emission intensity of fossil and especially coal fired energy production, these energy carriers will play an important role during the coming decades. In Germany, nuclear energy has to be replaced and in countries such as China or India the high and still growing energy demand requires the use of coal in addition to renewable energy sources. The existing resources of coal are with 14.800 billion tons still sufficient for the next century (Löschel, 2009). 44% of the hard coal resources may be assigned to the USA, 28% to China and 18% to Russia. The resources of lignite (brown coal) are also considerable: 4,200 billion tons (33% USA, 31% Russia, 15% China, 1% Germany). A further argument for coal consists in the fact that it is in most countries cheaper compared to the use of natural gas.

In Germany hard coal (22.8%) and brown coal (25.5%) contributed to nearly half of the whole electricity production in 2007. Following a scenario of IEA (2007), the relevance of the use of coal will not shrink until 2030, for the EU 27 the share of 30% will remain, in China we will still observe a value of around 80% concerning the electricity production. Even if we consider a scenario with a higher use of energy efficiency improvements, China will produce more than 60% of its electricity by the use of coal (see Löschel 2009).

Against this background, cleaner and more efficient coal-fired power plants will have an important role to play for both global energy and climate policy in the future. This study will identify the lead market strategies of four major countries in the global coal power plant market (China, Germany, Japan and the USA) regarding the main innovations of clean coal technology. The lead market approach for environmental innovations as developed by Beise and Rennings (2005) has identified six success factors for lead markets: Comparative price and demand advantages, a high reputation in environmental technology (transfer advantage), similar market conditions (export advantage), a competitive market structure and ambitious environmental regulation. We will also take further supply side aspects and the very different regulation schemes in those countries into account (see also Rennings and Cleff 2011, and Tiwari and Herstatt 2011). Our ex-post analysis tries to identify the existence of lead markets for the most important efficient, “clean coal” technologies compared to the scenario that a “second follower strategy” fits better for these technologies.

The most important technological trajectory of fossil fuel power plants is the pulverized combustion with a share of 90% of coal-fired capacity worldwide (WCI 2005, see also Rennings and Smidt 2010), so that this technology will be in the focus of our case study. Another reason is that we want to concentrate on technologies that have already left the demonstration phase. This is the case for subcritical, super- and ultra-supercritical pulverized coal technologies that are already established whereas for technologies such as Carbon Capture Storage (CCS) no diffusion curves can be derived yet due to their early phase of innovation.

The paper is structured as follows: Section 2 describes the relevant clean coal technologies. In Section 3, we derive their diffusion curves for Germany, China, Japan and the USA. Section 4 applies the lead market approach to the case of efficient coal technologies. Section 5 takes additionally supply side factors into account. In Section 6, we report on strategies for German firms based on expert interviews. Section 7 summarizes the results and concludes.

2 Coal Power Plant Technology Description

In general terms, a clean coal technology may be defined as a "technology that when implemented improves the environmental performance and efficiency as compared to the current state-of-the art in coal fired power plants" (Buchan and Cao 2004). Coal-fired power stations with pulverized bed combustion are differentiated and called by the steam conditions when entering the turbine, although it is not the only property which characterizes a coal-fired power station. Other important characteristics are the condenser pressure or the efficiency of the turbine (RWE Power AG 2011, IEA 2010a).

The steam conditions are divided in subcritical-, supercritical- and ultra-supercritical-conditions. Steam is called supercritical, when the steam parameters exceed the critical point[1]. The higher the temperature and pressure of the steam is, the higher the efficiency of the power plant.[2] A subcritical power plant works with a steam temperature about 540 °C or less and a pressure about 160 bar, which lies under the critical point. This technology is obsolete and

[1] Critical point describes the temperature and pressure above which the working fluid – in this case water – no longer turns into steam but instead decreases in density when it is heated above 'boiling point'. By eliminating the transition into steam (phase change) the efficiency of the process can be improved. For water the actual conditions are temperatures and pressures of over 374°C and 221.2 bar respectively.

[2] The rule of thumb in power plant construction is that each additional bar causes a 0.005% increase in degree of efficiency and each additional degree Celsius causes a 0.011% increase.

was removed by the supercritical power plants. Here, the steam temperature lies between 540 °C and 600 °C and the pressure between 230 bar and 270 bar. Temperatures of 600 °C with a pressure of 270 bar are state of the art and are called ultra-supercritical. Applying this technology, an efficiency of 40% - 43% can be achieved. Technologies characterized by temperatures of 700°C and pressures of 375 bar will be called advanced ultra-supercritical.[3] The so-defined advanced ultra-supercritical power plants are currently applied in some projects only, because of the high costs of materials which can resist this temperature and the pressure (IEA, 2010). Therefore nickel alloys will be developed. An efficiency of 50% can be reached with this technology (Energy 2.0, 2008).

The main improvements in power plant technology focus on efficiency and on the decrease of emissions. To achieve these targets, knowledge of many disciplines is required, because improvements are often based on incremental changes in different technologies. The diffusion of new technologies in coal-fired power plants is slow due to a long average life time of 35-40 years, and the risk of the high investments which leads to risk-averse investment decisions (Rennings et al., 2010).

Our case study will analyze the diffusion of supercritical and ultra-supercritical power plants as innovative solutions compared to the older subcritical plants.

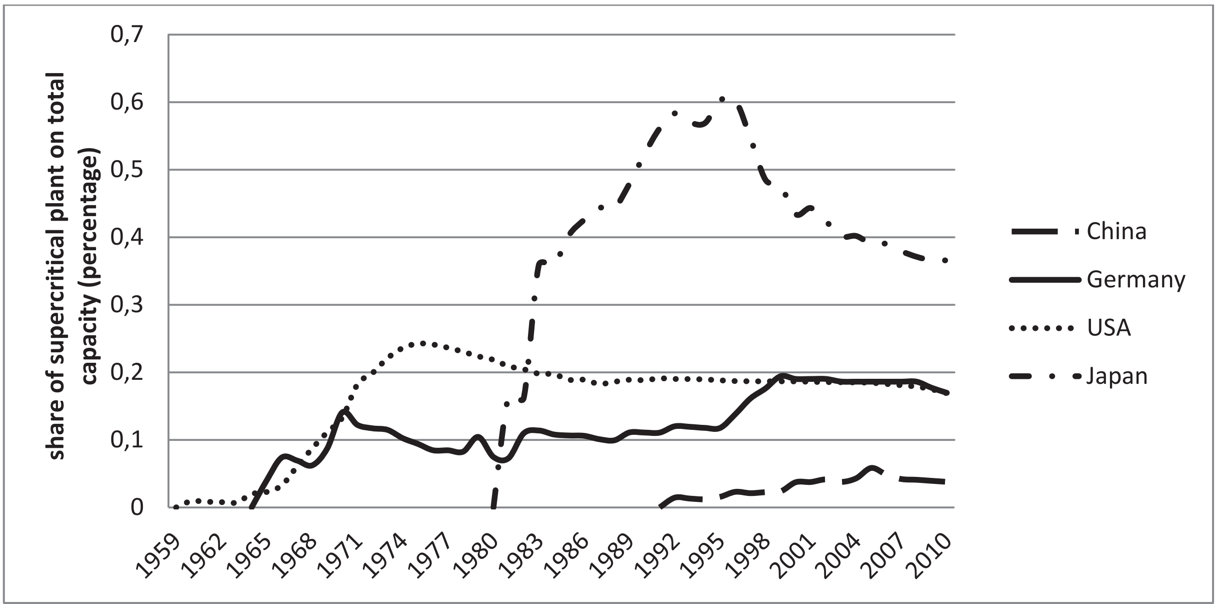
3 Diffusion Curves

Diffusion curve of supercritical pulverized coal technology

Supercritical pulverized coal technology is one of the most common technologies among coal-fired electricity generation. This technology has been used for several decades (since 1959) and realises its diffusion in the United States, Germany, Japan and China. Figure 1 shows the diffusion curve over time as the share of supercritical power plants on the entire installed capacity of coal-fired power plants in a country, which means the accumulative installed capacity of supercritical power plants/ total installed capacity per year.

[3] The IEA coal database already defines technologies as ultra-supercritical that are characterized by a steam pressure of more than 250 bar combined with a steam temperature of at least 550 °C. The diffusion curves in Section 3 are calculated following this definition.

Figure 1: Diffusion curve of Supercritical pulverized coal technology in selected countries



Source: IEA (2011a), own calculations.

USA

The United States was the leader in designing and manufacturing supercritical pulverized coal technology in the late 1950s. In 1959, the first coal-fired supercritical power unit Avon Lake 8 was commissioned in the USA and in 1960 four more supercritical power units followed. Then this technology developed well especially after the material problems were overcome in the second half of 1960's (Rennings and Smidt, 2010). The share of supercritical power plants rose constantly and reached its peak (24.1%) in 1976 and then it came to a stop in the late 1970's and remains by 20% up to now.

Germany

Germany quickly followed the USA in adopting supercritical power plants since 1965. Just like in the United States, the diffusion of supercritical plants seemed promising in the beginning. However, just after reaching a market share of 14.1% in 1970, the diffusion of supercritical power plants stopped and declined again to about 7.3% in 1981. After the reunification of Germany in 1990 the ratio of supercritical to subcritical power units rose again. The government's commitment to advance the state-of-the-art pulverized coal technology was the most important driver to the development of supercritical technology. The peak of the diffusion rate of supercritical power units reached 19.4% in 1999 and it declined to 17% in 2010. Beginning from 1999, Germany concentrated on the construction of ultra-supercritical plants characterized by steam temperatures of 550 °C and more (following the definition of The IEA coal database, see also Figure 2).

Japan

Japan started constructing supercritical plants in the 1970s, and caught up in the next decades. Influenced by the oil price crisis, the share of Japanese supercritical power plants quickly rose from zero in 1980 to 60.2% in 1996, at an annual growth rate of 27.3%. The total installed capacity in 1996 was 11900 MW in Japan. After then it started to decline to 36.6% in 2010.

China

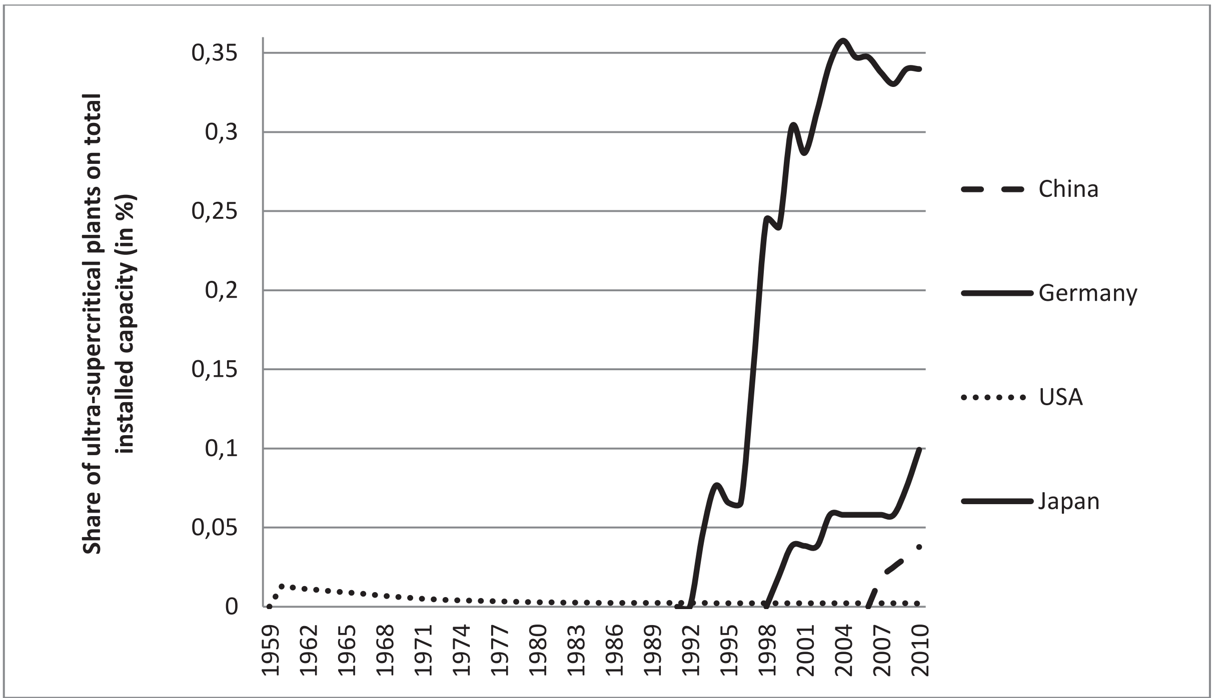
China is the last country regarding the development of supercritical pulverized coal technology of the four countries. China started using supercritical technology in the 1990s with the procurement of ten units from Russia. Since then, many more supercritical units were built and approximately 27 were in operation at the end of 2010. Sixty percent of the new plants that started construction after 2005 and represent a total of 37.8 GW (600 MW each) are supercritical. From 2010 to 2020, new power plants with unit capacities of 600 MW and more will all be required to be supercritical and about half of the newly built power generating units will be ultra-supercritical. Consequently, supercritical units will account over 30% by 2020 (Huang, 2008).

It seems that the USA first takes over the role of a lead market in the 1960's and during the following 20 years. Other countries followed the American innovation design, such as Germany in the 1960's and Japan in the 1970's. So far, the lead markets model argues that lead markets do not switch to other countries but are "stable". This has been supported by several empirical analyses such as the diffusion of cellular phones, facsimile machine; diesel motors with direct injection, etc. (see Beise 2001, Beise and Rennings 2005). However in this case, the diffusion curves overlap by Japan in the early 1980's since America stopped to build new supercritical power plants (Rennings and Smidt, 2010).

Diffusion curve of ultra-supercritical pulverized coal technology

The diffusion of ultra-supercritical pulverized coal technology (USC) paints a similar picture to what was already indicated in the analysis of supercritical pulverized coal technology. The first USC plant in the world was Ohio Power's (now American Electric Power) Philo unit 6 in the USA in 1960. Not as expected, America decided to abandon this technology on the domestic market since 1960, only one year after the first ultra-supercritical pulverized power plant was built. Since then it lost its lead market role although it was the first who designed and manufactured ultra-supercritical power plants. Ultra-supercritical power plants first appeared in the USA, but other countries joined in applying the technology. For example, instead of Germany, Japan picked up ultra-supercritical pulverized coal technology in 1993. As a second mover, Japan was the major driver for USC technologies during the 1990s and became the technology leader before 2005. Germany started with the diffusion of this technology in 1999. Although China is still the last country that introduced this technology in 2007, commercial adoption of ultra-supercritical technology is expanding rapidly. Supercritical and USC used to represent a small percentage of the newly ordered power plants (10%-30%) before 2002, but in recent years they represent more than 60 percent of all coal power plants in China. And there are 23 USC power plants with 33 GW-level USC units operating in China at the end of 2010, while 11 more were under construction (CEC, 2011).

Figure 2: Diffusion curve of Ultra-supercritical coal-fired power plants



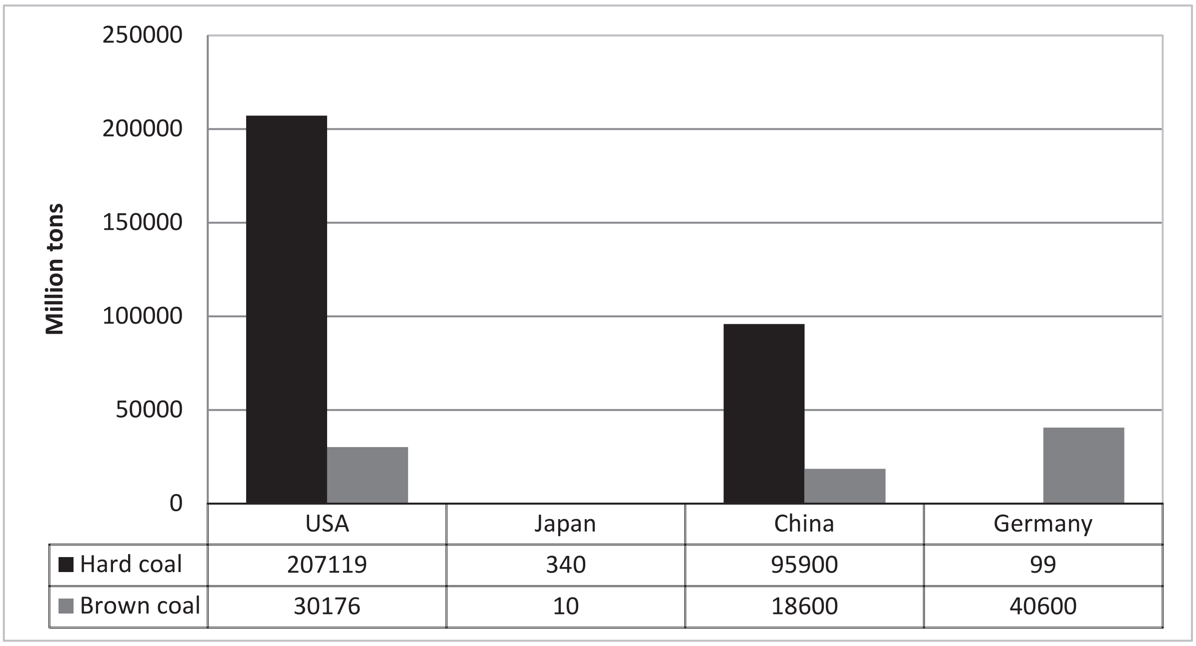
Source: IEA (2011a), own calculations.

4 Lead Market Factors

4.1 Price advantage

The price advantages can be measured by using different indicators: proved reserves, fuel costs, absolute and comparative cost advantage. First, proved reserves are defined by the IEA (2007, p. I. 9) as all resources "…that are not only confidently considered to be recoverable but also can be recovered economically, under current market conditions." This means that using proved reserve data makes it unnecessary to take national differences in accessibility and extracting costs into account. It is an indicator of the supply side for relative cost advantages regarding resources. Figure 3 shows the proved recoverable coal reserves [in million short tons] in the different countries.

Figure 3: Proved hard and brown coal reserves in 2008 of selected countries



	USA	Japan	China	Germany
Hard coal	207119	340	95900	99
Brown coal	30176	10	18600	40600

Source: IEA (2011b).

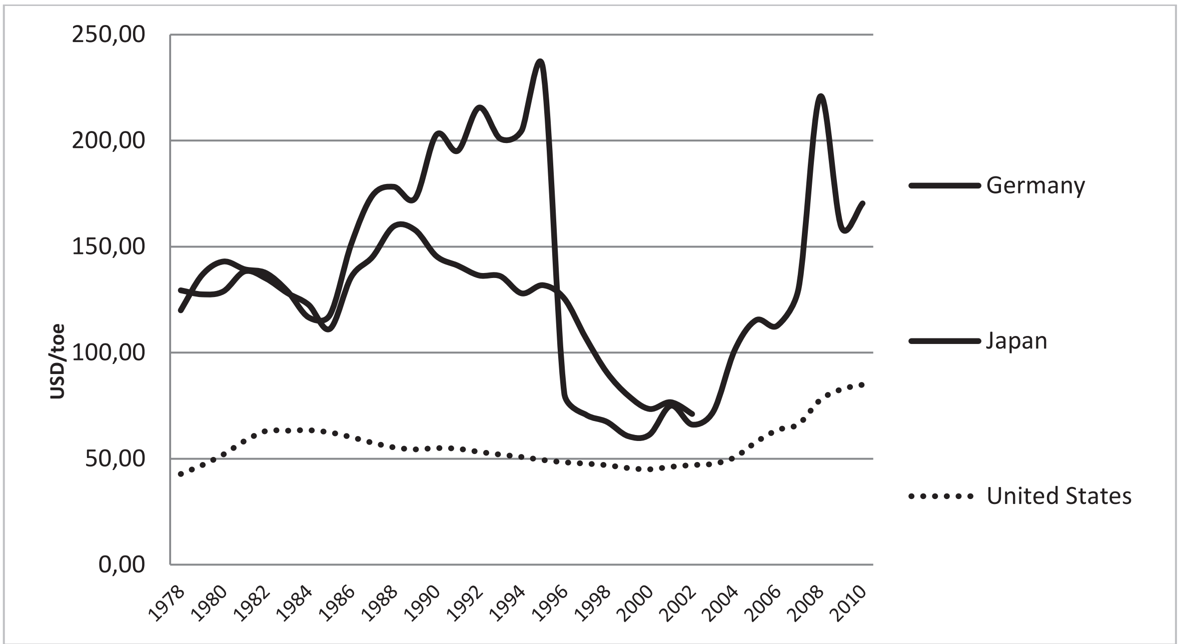
There is a great inequality concerning the spread of reserves across the globe. If it is assumed that importing fuels is more expensive than extracting own reserves, then the endowment of a country regarding coal reserves decides whether it has a price advantage or not. The usefulness of proved resources as an indicator for price advantages is however limited. It is possible that a country is not able to make use of its reserves, because it is not permitted by the national energy policy. Then, of course, the rich reserve with coal is no advantage for a country.

Reliable data concerning proved reserves are only accessible for very few points in time. No time series are available and the publicly availably publications only cover the time from the late 1990s onwards. The data used for the analysis are from IEA statistics on “Coal information 2011”.

As Figure 3 shows, the United States own the far largest coal reserves in the world (IEA, 2011). The structure of coal reserves in both USA and China is similar. 87.3% of total reserved coal is hard coal in USA and 83.8% in China. Germany has only abundant reserves concerning brown coal and Japan’s total proved coal reserves are negligible. Following Beise’s argumentation (Beise 2001), USA has a price advantage caused by its abundant coal reserves compared to the other countries.

Fuel prices also give information about the price advantage of a country. Figure 4 shows the steam coal price paid by utilities in each country (except China) for electricity generation (US$/toe). Data is often not reported for countries that rely to a large extent on domestic coal production and for those countries whose mining sector is state owned. This applies for China, where data about coal prices is not available. Furthermore, tax reductions and other privileges may distort the picture painted by the analysis of fuel costs. It may occur that a country has to pay high import prices and has no reserves that it can rely on, but domestic regulation compensates for the high fuel prices.

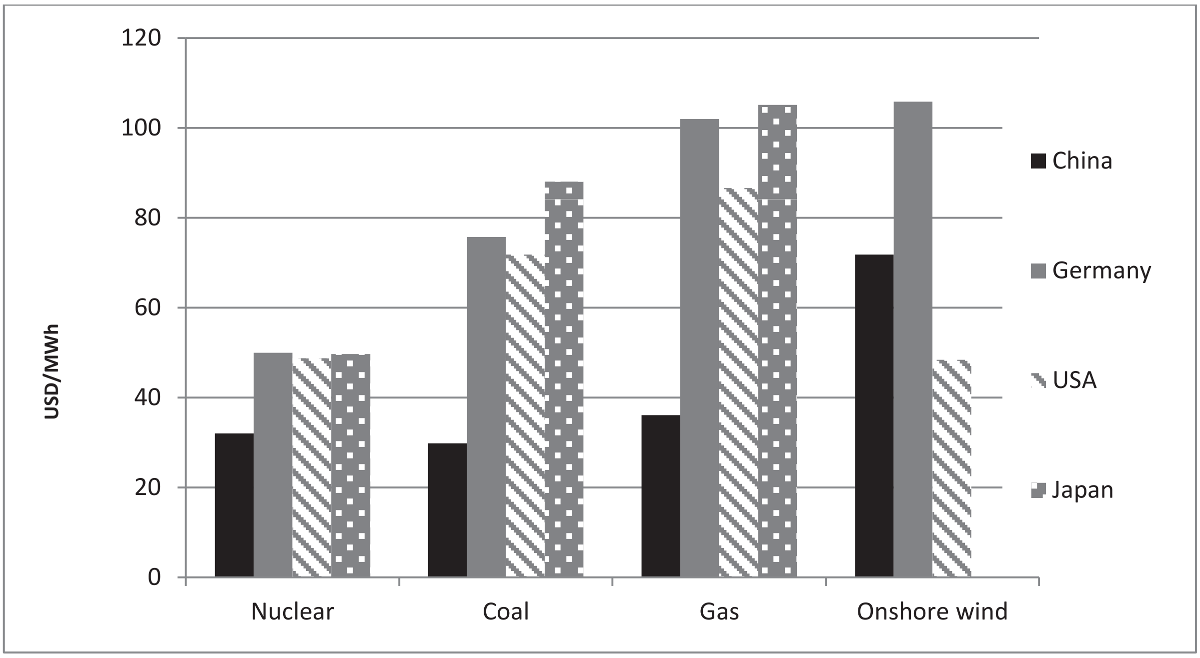
Figure 4: Steam coal price paid by utilities for electricity generation



Source: IEA (2011c).

The analysis of the fuel price data shows that the USA has a definite price advantage compared to Japan and Germany. Not only did American utilities sometimes pay less than a third of what Japanese and German utilities had to pay, the price for steam coal in the US also remained relatively stable. Germany is a perfect example of how state regulation can influence the costs of utilities. Until 1994, German utilities were forced to buy steam coal out of domestic production, which operated – due to unfavorable geological conditions – on an uneconomical level. This led to steam coal prices exceeding those in Japan by far. Prices dropped immediately after the act was abolished in 1994. The USA maintains its price advantage throughout the entire time.
A third indicator for the price advantage of a country is the absolute cost advantage in terms of electricity generating costs for the main energy sources (see Figure 5).

Figure 5: Leveled cost of electricity from four energy sources in selected countries[4]



Source: IEA (2011d).

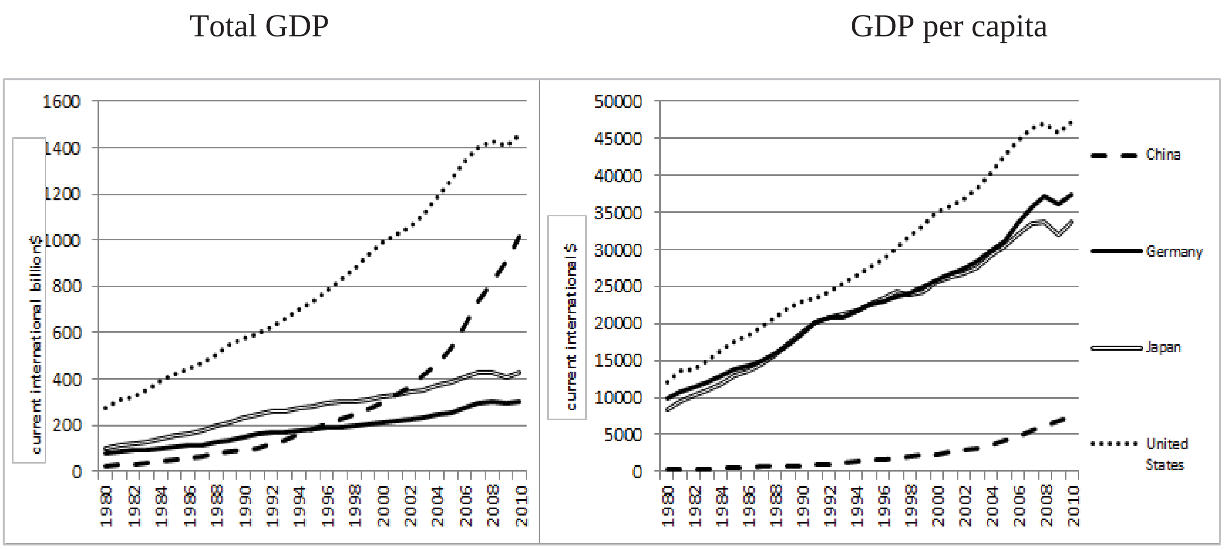
The analysis of the electricity costs for the main energy sources shows that China has a definite cost advantage compared to the other three countries whereas Japan is characterized by the highest electricity costs reflecting the low endowment with energy resources.

[4] USA, Germany and Japan: Black coal pulverized coal combustion technologies; China: Black coal supercritical coal combustion technologies.

4.2 Demand advantage

Per capita income can be used as an indicator for demand advantages. The wealth of a nation plays a positive role on the rate and time of adoption of innovations (Dekimpe et al. (1998) and Vernon (1979)). From a supply perspective, it may increase the motivation to invest in new technologies and from a consumer perspective it reflects a greater willingness to pay for new products. However, the correlation between income and the rate a nd time of adoption of innovations has been mostly proven for consumer goods (Beise 2001, p. 91) whereas the innovative behavior of firms strongly depends on further factors such as the existence of innovative capacities or a highly qualified staff. Figure 6 shows the total GDP and GDP per capita (current international $, in Purchase Power Parities (PPP)) in the selected countries.

Figure 6: Total GDP and GDP per capita (current international $, in PPP) of selected countries



Source: Word data bank (2011a).

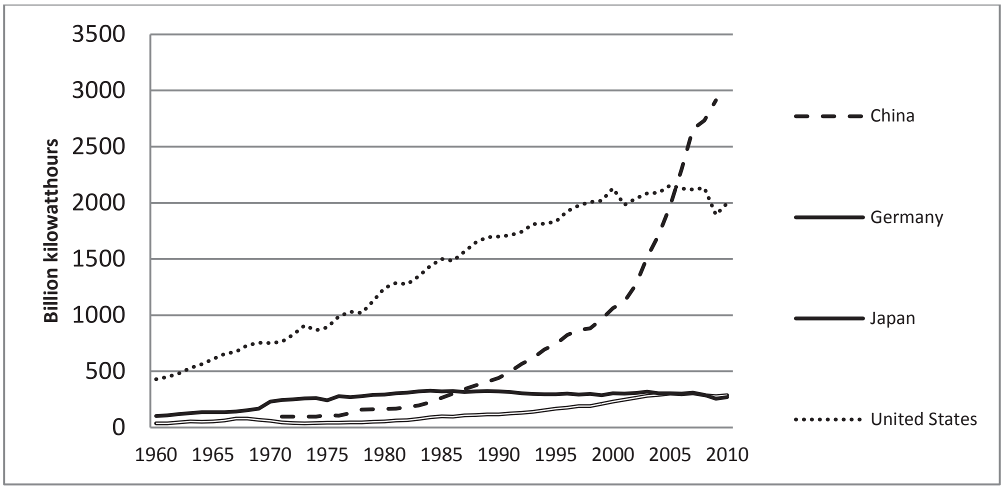
Among the four countries examined in this study, the USA shows the highest total GDP. China´s total GDP grew rapidly during the last two decades and passed Germany in 2007 and Japan in 2009, becoming the second largest economy in the world.

The GDP per capita shows another picture: The USA is characterized by the highest income per capita, Germany and Japan follow closely. China’s income-per-capita in 2010 was only 4354 $. Summarized, the USA seems to have a demand advantage over the other three countries, followed by Japan, then Germany and China. Given the high growth rate of GDP during the last decades, China can however be expected to take over the lead regarding demand advantages in future.

Electricity intensity can be interpreted as a second indicator for demand advantages. It can be assumed that those countries with a high coal-based electricity production will also show high demand for new and efficient coal-fired technologies. The figures 7-9 show the electricity production from coal sources, the total thermal electricity intensity of GDP and the share of coal on total electricity output in the selected countries.

Since 2010, China is the second largest electricity consumer with 4190000 Gigawatt hour (GWh), very close to USA with 4361401 GWh in 2010. However, after nearly 10% annual economic growth in the past decades and tripling its coal electricity production since 1970, China has already surpassed the USA regarding coal electricity production since 2006. In contrast to the stable trend in the three other countries, there was a rapid increase in the coal electricity production since 2006.

Figure 7: Electricity production from coal sources in selected countries between 1960 and 2010 [GWh]

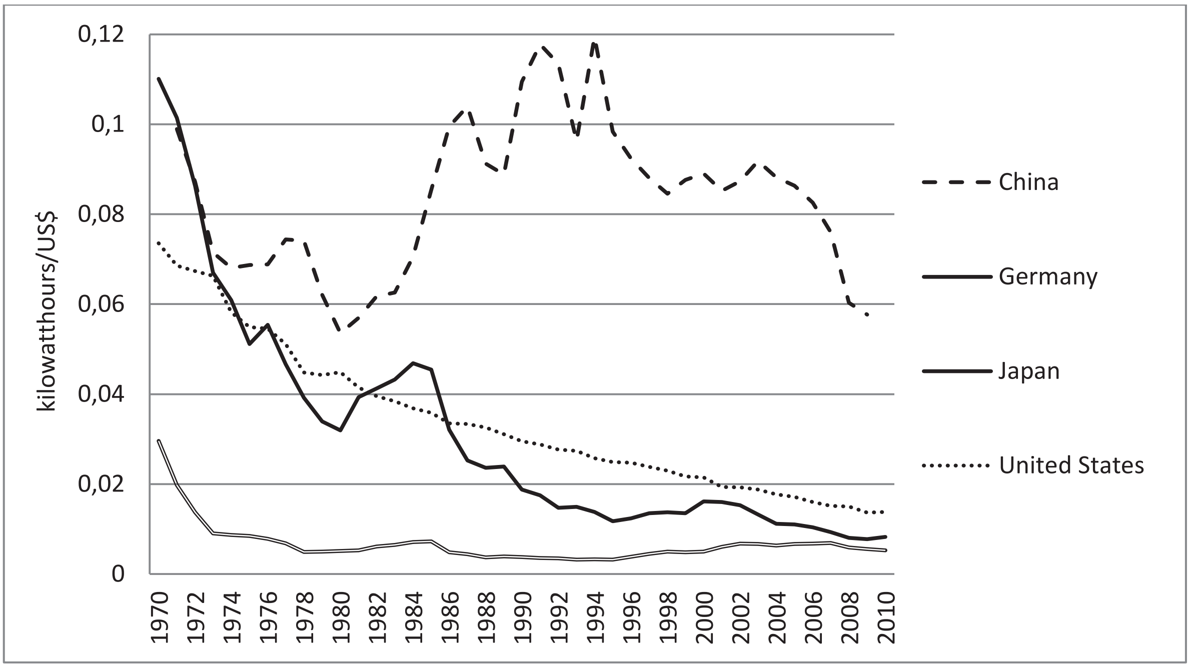


Source: World bank database (2011b).

Figure 8 shows the amount of production of electricity generated from coal per $ GDP, i.e. the electricity intensity of each country. In 2010 China produces 0.07 kWh per $ GDP and thus has a demand advantage, while the USA (0.014 kWh/$) cannot keep their “leading” position. Germany (0.008 kWh/$) and Japan (0.005 kWh/$) are less electricity intensive.

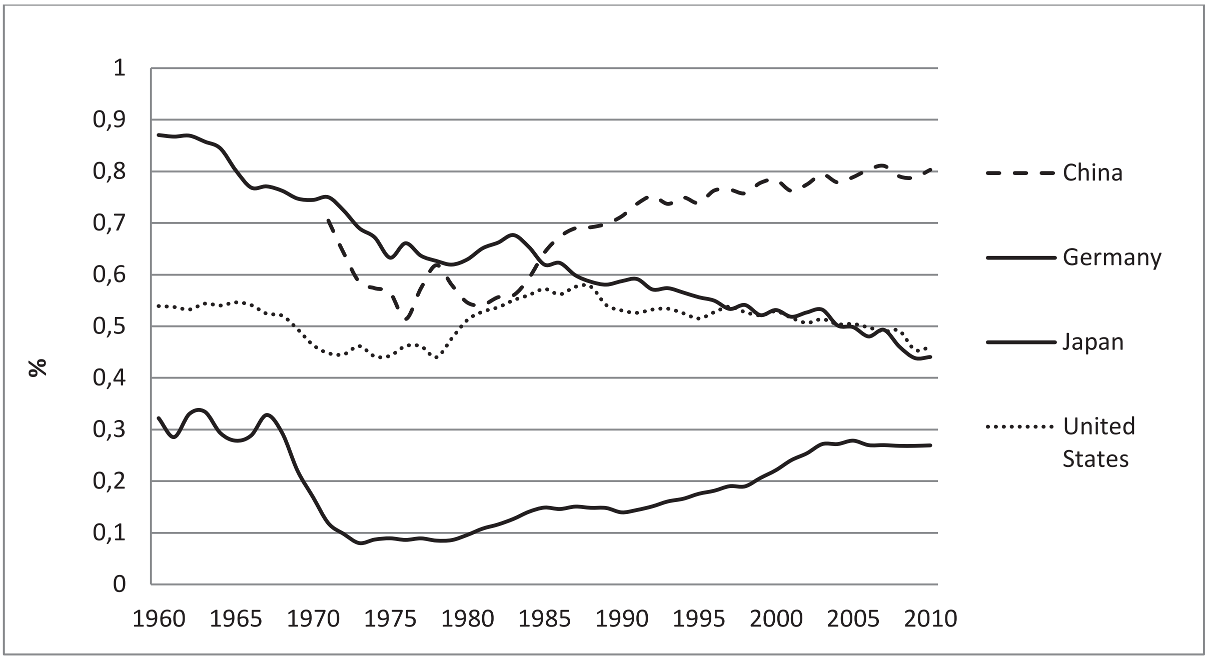
As technical equipment gets more efficient in general and electricity prices keep rising, all countries have experienced a decrease in electricity intensity over the last decade. Especially in China, the electricity intensity declined by 41.7% during 1971-2009.

Figure 8: Total thermal electricity intensity of GDP of selected countries between 1970-2010



Source: World bank database (2011b).

Figure 9: Share of coal on total electricity output of selected countries

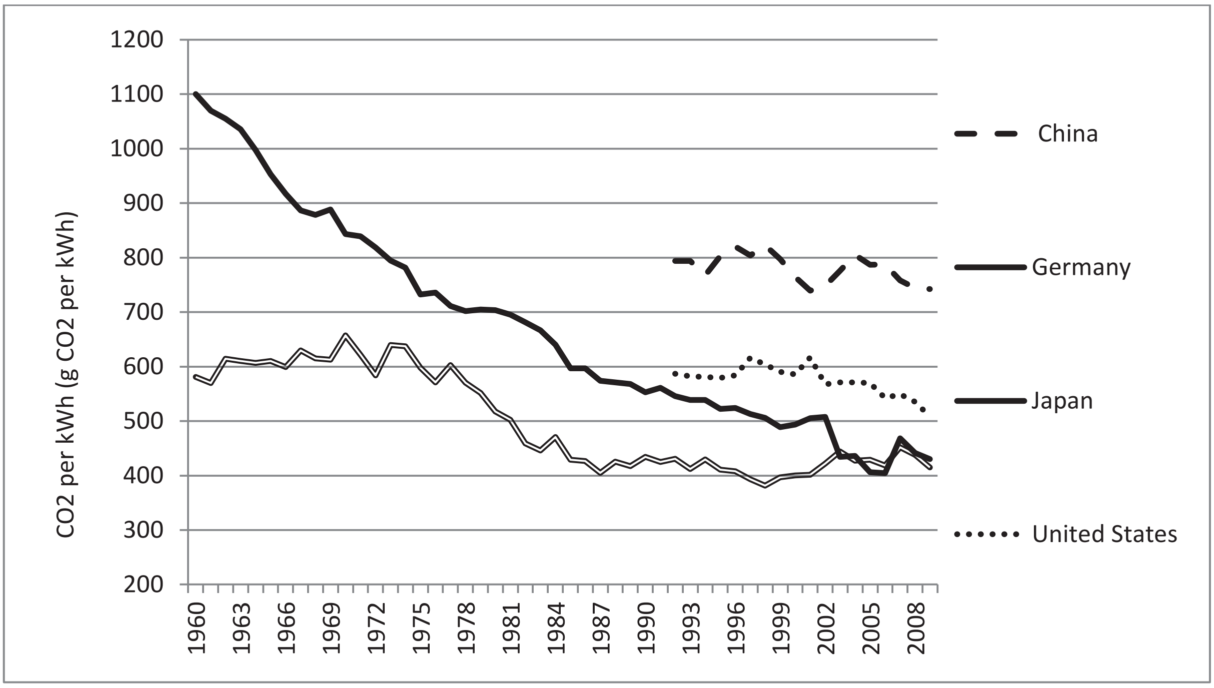


Source: World bank database (2011b).

Since the mid-1980s China shows the highest coal shares on total electricity output compared to the other three countries (see Figure 9). In 2010, more than 80 % of the Chinese electricity production was based on coal. Germany, on the other hand, shows an opposite development. The coal share decreased substantially since the 1960's from 87% in 1960 to 44% in 2010.

The USA shows a relatively stable share of coal-based power generation of around 50%. Japan has seen a very instable role of coal throughout the course of time. After a decrease before 1975 the share of coal rose again. Currently coal contributes 24.9% in 2010 to support Japan's power supply.

Figure 10: CO_2 intensity of total electricity and heat output in selected countries

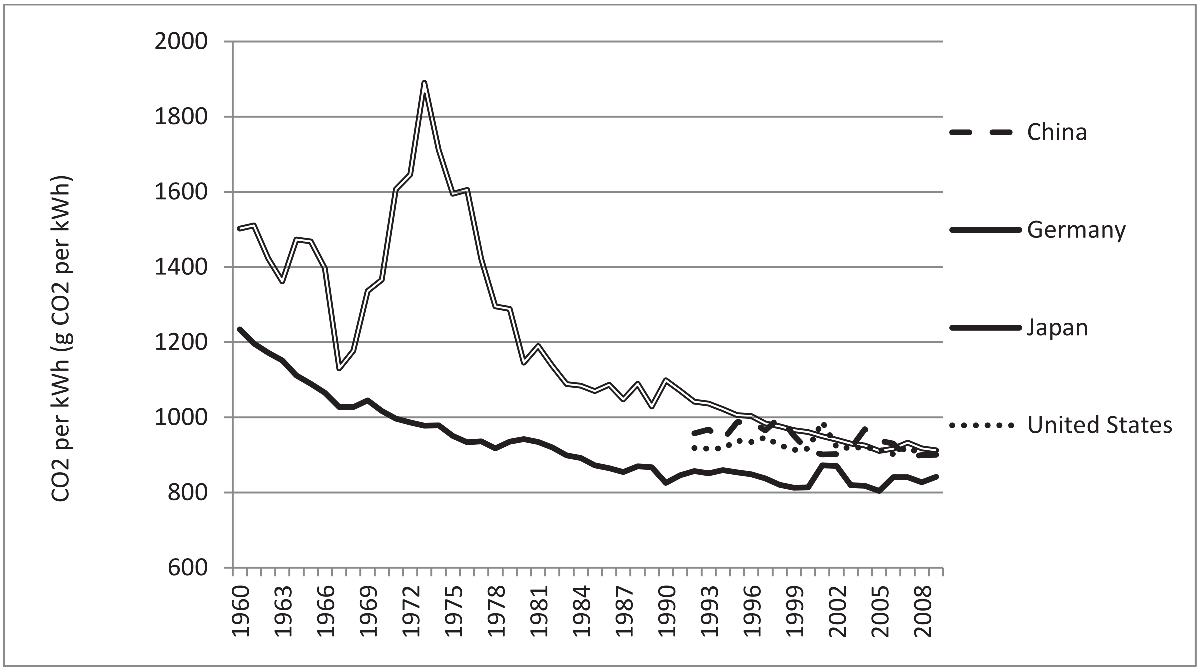


Source: IEA (2010b). *data was missing in China and Unite State before1992

CO_2 intensity of electricity production can also be regarded as indicator for demand advantages. As climate change became the global issue, countries with high CO_2 emission and high CO_2 intensity of electricity from coal face high political pressure from other countries to improve their CO_2 performance. These countries will likely invest in low carbon technologies, including clean coal. A limitation of this indicator is that countries with a high CO_2 intensity of the electricity sector may also switch to other energy resources such as renewables to produce electricity. Figure 10 and 11 show CO_2 intensity of total electricity and heat output and from coal source in the selected countries.

The two figures show that there is a declining trend regarding CO_2 intensity of electricity and heat output in the selected countries. Due to a still high CO_2 intensity of total electricity, China and USA have a relative demand advantage. However the advantages become smaller regarding the CO_2 intensity of electricity and heat output from coal.

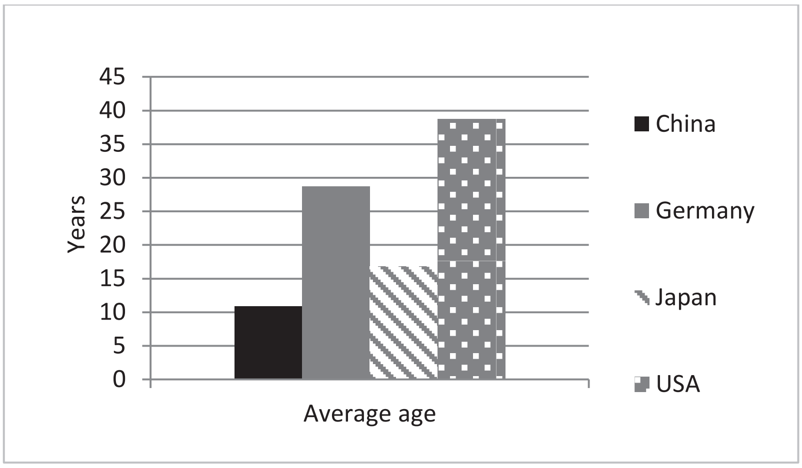
Figure 11: CO2 intensity of electricity and heat output from coal in selected countries



Source: IEA (2010b). * data was missing in China and USA before1992

The average age of power stations, as shown in Figure 12, can be seen as the last indicator for demand advantages. Countries characterized by high average plant age have a demand advantage since the power plants can be expected to be replaced soon. Coal-fired power plants do usually run for a period of 25-35 years. The United States has the highest average age of their coal-fired power plants.

Figure 12: Average age of coal-fired power plants in selected countries in 2010

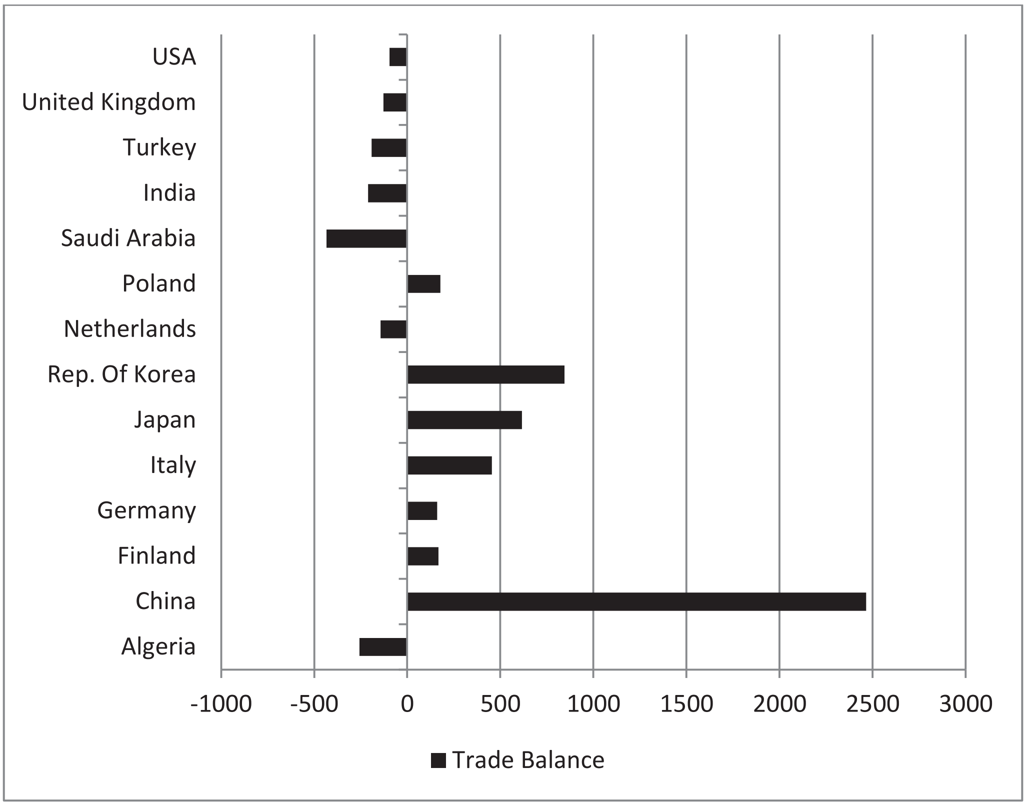


Source: IEA (2011a).

4.3 Export advantage

In the following, we try to assess which countries are specialized in the production of clean coal technologies and successful in selling clean coal equipment to other countries. To measure the export advantage, we use the trade balance (exports – import) in 2010 and the development of the export/import ratio from 2007 to 2010. The UN Comtrade data basis provides such data not explicitly for clean coal technologies but for the product groups “steam boilers” and “steam turbines”.

Figure 13: Trade Balance Steam Boilers in 2010, in millions US $



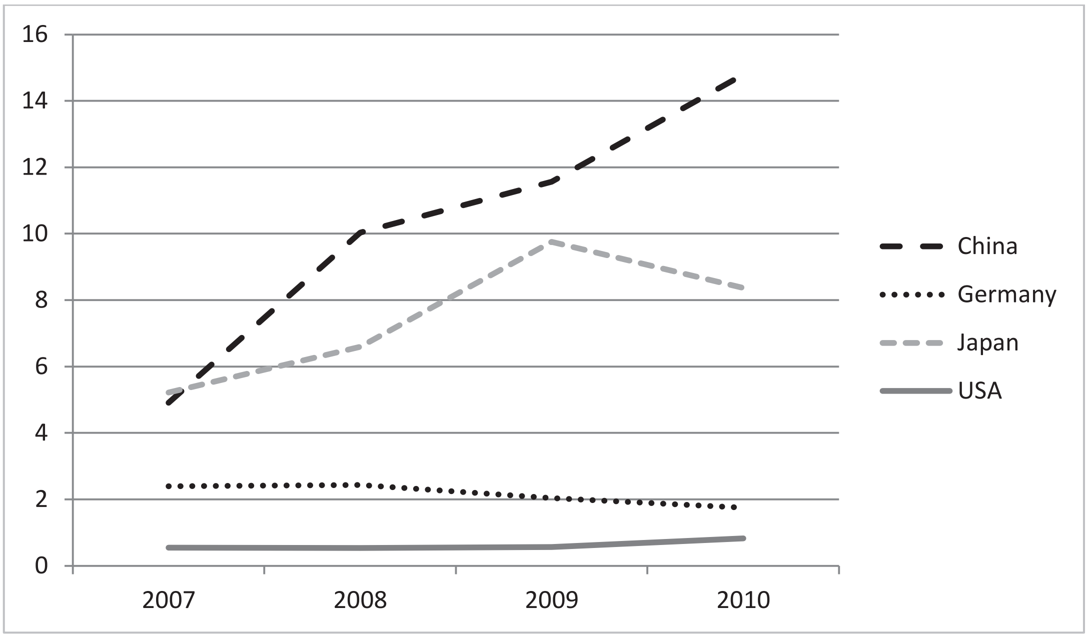
Source: UN (2012).

Figure 13 shows that China is highly specialized in the production of steam boilers even dominating the Republic of Korea and Japan. Following the results of expert interviews with power plant and component producers (see also Section 6) this statistic does not tell the whole story because China predominantly exports parts of boilers that have to be completed by the high-tech products of Japanese or German firms. Japan and Germany are also net exporters of steam boilers whereas the USA is even a net importer.

The development of the export/import ratio from 2007 to 2010 confirms these results: From 2008 China shows the highest export/import ratio followed by also high values of Japan. For

Germany, this value even declined slightly from 2007 to 2010 confirming the lower importance of Germany as a production location for these products. In the USA, we observe a slight increase but the ratio remains below the value one.

Figure 14: Steam Boilers: Development of export-import ratios from 2007 to 2010

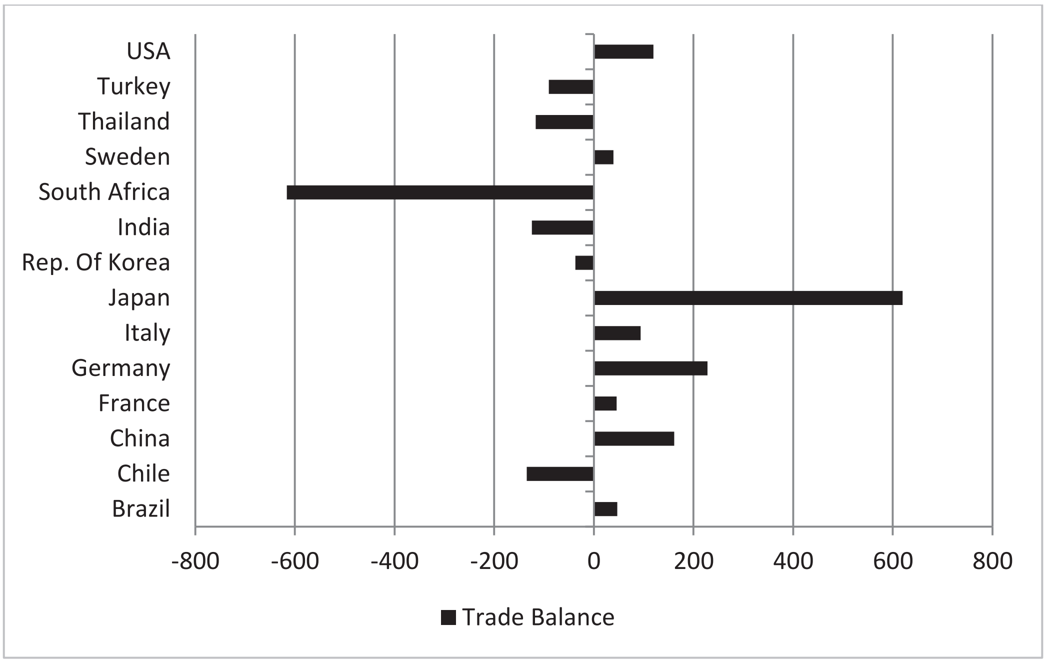


Source: UN (2012).

Concerning steam turbines, Japan seems to be the most specialized country documented by a high trade surplus in 2010 (Figure 15) and very high export/import ratios from 2007 to 2010 (Figure 16) compared to the other countries. Especially Germany, but also China and the USA also show high net exports in 2010 for steam turbines.

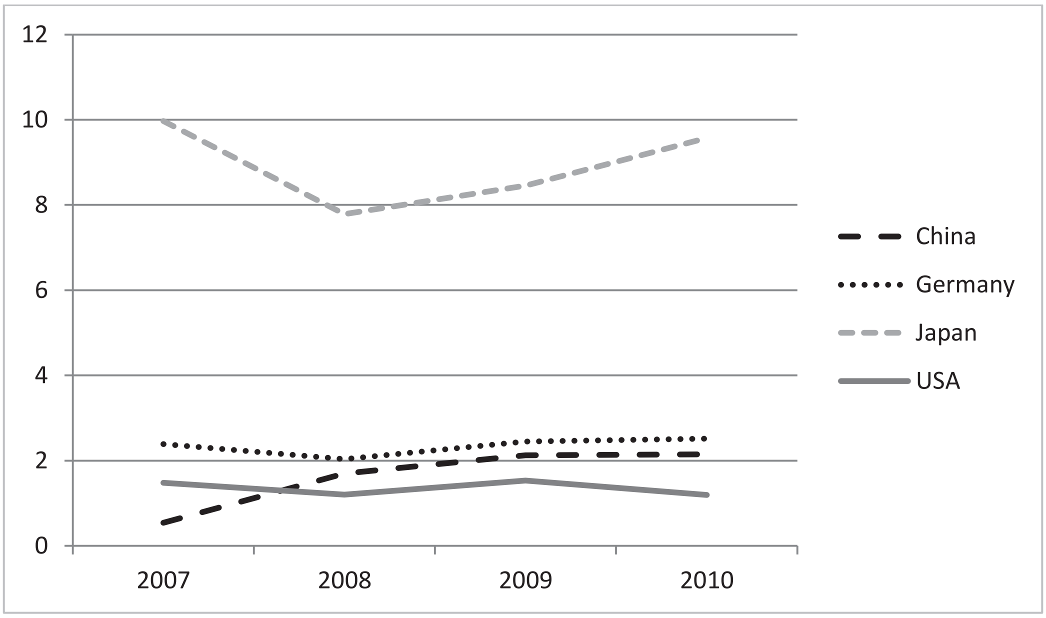
As concerns the trade balance and the export/import ratio, Germany still remains beyond China whereas the export/import ratio of the USA is now lower than that of China.

Figure 15: Trade Balance Steam Turbines in 2010, in millions US $



Source: UN (2012).

Figure 16: Steam Turbines: Development of export-import ratios from 2007 to 2010



Source: UN (2012).

Summing up, China seems to have an export advantage for steam boilers, whereas Japan holds this position for steam turbines. Due to the growing importance of highly efficient coal power plants requiring "high-tech" steam boilers, the Chinese producers will only keep their export advantage if they are able to improve the technical quality of their boilers.

4.4 Transfer advantage

On the one hand, the transfer advantage describes the capability of a country to be or to become a lead market in the respective technology. On the other hand, but closely correlated to the capability, a country shows a high transfer advantage if the international reputation and attention regarding the specific technology is high (see Rennings and Smidt 2010).

To measure the transfer advantage for efficient coal technologies, we use the following indicators:

- Degree to which R&D matters in a country;
- R&D related to coal technologies and CCS (Carbon Capture Storage);
- Number of demonstration plants in a country;
- Efficiency of coal fired power plants (Output of electricity sector/Input electricity sector).

Table 1: Indicators Transfer Advantage

Country	R&D in general (2007/8/9) in % of GDP	R&D related to coal and CCS (2010) in % of GDP	Number of demonstration plants (2007)	Average Efficiency of coal fired power plants (2005)
Germany	2.82	0.00086	8	39.0
Japan	3.44	0.00267	21	42.0
USA	2.79	0.00256	12	36.4
China	1.5	-	9	31.0

Source: OECD (2012), IEA (2011a), Rennings and Smidt (2010).

The results for our indicators (see Table 1) show a clear transfer advantage for Japan. The average efficiency of coal-fired power plants is the highest, furthermore Japan is characterized by the highest number of demonstration plants and percentage of R&D in general and also related to coal technologies.

Table 2: Total R&D related to Coal Technologies (including Carbon Capture Stor-age) and renewable resources in million US $ (2010 prices and exchange rates)

Countries and Technologies	2005	2008	2010
Germany			
Coal (production, preparation, transport)	10.462	41.359	12.008
CO_2 capture and storage	5.625	3.856	17.046
Renewable energy sources	127.823	160.589	248.403
Japan			
Coal (production, preparation, transport)	160.806	90.468	18.295
CO_2 capture and storage	-	42.153	127.372
Renewable energy sources	277.8	223.188	236.845
USA			
Coal (production, preparation, transport)	269.119	349.271	148.0
CO_2 capture and storage	69.5	196.264	225
Renewable energy sources	277.115	456.737	1310

Source: IEA (2012).

Compared to renewable energy sources, the total R&D expenses related to coal technologies are very small in Germany (see Table 2). In Japan, the research for renewables has also a high importance but the R&D expenses for clean coal technologies are still very high supporting the result that Japan has a transfer advantage. From 2005 to 2010, interestingly, the R&D expenses in Japan shifted significantly from coal production technologies to CCS what is also the case in the USA.

4.5 Regulation advantage

In the following, we analyze indicators describing the regulation environment for the realization of clean coal technologies in the US, Germany, Japan and China. “A country has a regulation advantage if the legal framework allows companies to plan on a mid- and long-term scale and at the same time exerts pressure on firms to come up with innovative ideas” (Rennings and Smidt 2010). To analyze a regulation advantage for clean coal technologies indicators such as the existence of carbon-taxes and/or an emissions trading system, the importance of renewable energy electricity production and the social acceptance of coal technologies are useful.

Because of the high relative CO_2-emissions of coal compared to other energy sources the introduction of carbon-taxes or the implementation of an emissions trading system seems to be a very important driver of clean coal technologies. Furthermore, a high proportion of renewable energy electricity production may exert a pressure on the coal sector to become more efficient and less CO_2 intensive. At least in the long run, energy policy decisions are dependent on the acceptance of the society – the story of nuclear power being an excellent example for this argument. On the one hand, a low social acceptance for coal may trigger activities to develop cleaner coal technologies. But on the other hand, due to the fact that it is difficult to explain to a non-technician that coal may be "clean", the low social acceptance may also lead to a resistance against all "dirty" and "clean" coal technologies. Thus we will describe and compare the energy innovation systems and environmental policy in the four countries to identify which country has advantages regarding regulation.

Germany

Historical development

In the following, we give a short historical overview on the evolution of the coal policy in Germany showing drastic changes in the role of coal as energy source.[5]

The decade from **1970-1980** was still characterized by an explicit promotion of the production of electricity by hard coal. As a consequence of the so-called "3. Verstromungsgesetz" the electricity sector has been obliged to use a certain quantity of hard coal (justified by the security of electricity supply). On the other side, new oil or gas plants even needed an explicite permission. Furthermore, a subsidy compensating the high hauling cost for hard coal ("Steinkohlepfennig") was introduced to reduce the burden for the energy suppliers (see Fuchs et al. 2011).

During this time period, the construction of sub-critical coal power plants with a degree of effectiveness of 35% dominated. But on the other side, a more strict environmental policy (especially the "Bundesimmissionsschutzgesetz") emerged regulating the reduction of sulphur dioxide (SO_2) and NO_x (mainly by end-of-pipe measures).

During **1980-1990** more rigorous emission limits for SO_2, NO_x and dust have been introduced ("Großfeuerungsanlagenverordnung"). The second energy research program postulated an increase of energy efficiency and a reduction of energy imports. After the nuclear catastrophe in Tschernobyl (1986) the research in nuclear power technologies has been reduced. Because of the before-mentioned Großfeuerungsanlagenverordnung, six GW of old subcritical coal power plants were closed accompanied by an enlargement of electricity power-heat combina-

[5] For a comprehensive report see Fuchs et al. (2011).

tion (KWK), the construction of 11 GW new power plants on the basis of hard coal but despite the availability of supercritical technologies, most of the new power plants were still subcritical. The time period was also characterized by a further development of fluidized bed combustion (see Fuchs et al. 2011).

The coal policy from **1990-2000** was initially dominated by the reunification of Germany leading to high subsidization for new lignite based power plants in East Germany. The so-called "Kohlepfennig" was declared as illegal leading to a reduction of the use of hard coal in Germany, furthermore the restrictions for gas and oil fired power plants were abolished. As a consequence, only few hard coal based power plants with predominantly supercritical steam parameters (efficiency degrees of 43%) have been constructed. The liberalization of the energy market led to high cost pressures for the energy suppliers.

From **2000-2011** the energy policy in Germany was more and more oriented towards renewable energies. The 5th and 6th energy research program aims at making the energy system sustainable by using renewable energy. A well balanced energy mix using hard and brown coal shall be realized. An increase of energy efficiency against the background of increasing energy prices from 2005 to 2008 and a higher share of renewables connected with climate protection are in the focus. Concerning coal the use of CCS technologies has been proposed but the societal acceptance of this technology is very low in Germany.
The introduction of the CO_2 emission trade system can be understood as a disadvantage for the use of coal despite the fact that the prices of CO_2 emission permits remained moderate during this decade. Nevertheless, only few new fossil-based power plants have been constructed since 2000. The competition policy concerning energy was characterized by an introduction of a stock market for electricity and further liberalization of the electricity market.
In 2011, an agreement to phase-out nuclear energy was decided in Germany after the Fukushima accident, which may be a driver for the construction of new clean coal technologies.

Assessment of the regulation advantage for clean coal technologies in Germany

The general policy background for coal technologies in Germany is characterized by a low societal acceptance whereas the high subsidized renewable energies are in the focus of energy policy. As already shown, the coal policy strategy has strongly changed during 1970 to 2011 but the sixth energy research program of the German government from 2011 still contains important elements to promote clean coal technologies. An important institution is COORE-

TEC denoting CO_2 reduction technologies (see Bundesministerium für Wirtschaft und Technologie, 2011) for the use of fossil fuels. This initiative aims at

- an improvement of energy efficiency in fossil-fuel-fired power plants;
- the promotion of Carbon Capture Storage (CCS) technologies;
- system integration of power plants, network optimization, better connection of power plants with industrial processes.

Furthermore, European initiatives play an important role. Already in 1998, a group of major suppliers to the power industry and some of the major utilities in Europe started a 17-year demonstration project that was financially supported by the European Commission (European Commission 2011:74), namely the so-called Thermie 700°C. “The main aim of the THERMIE 700 °C steam coal power plant project is to make the jump from using steels to nickel-based super alloys for the highest temperatures in the steam cycle which should enable efficiencies in the range of 50-55 % to be achieved.” (European Commission 2011:74).

As regards the German innovation policy, the sixth energy research program shows that coal technologies are not in the focus of innovation policy and subsidies because of the high attention towards renewables but the program confirms that the improvement of the use of coal for electricity production is necessary despite a low societal acceptance. In fact, the environmental policy goes in a similar direction. Renewable energy is highly subsidized, on the other side eco-taxes and the European Emission Trade System (ETS) lead to a higher burden of fossil fuel energy suppliers and energy consumers. The negative effect of environmental policy (e. g. ETS) is moderated because the amount of permits for energy suppliers were high and mainly costless because a grandfathering allocation system was still in use. Furthermore, there are still exceptions for energy suppliers concerning eco-taxes. From the side of the industrial policy, too, the liberalization of the electricity market led to a higher competition and costs for fossil fuel energy suppliers.

In a nutshell, Germany lost much of its regulation advantage for clean coal technologies during the last ten years because of a clear cut change of paradigm towards renewables. It may be true that this new strategy also triggers the development of more efficient coal technologies but on the other hand the coal sector lost much of its financial support by the state in favor of renewables. In the long run, it can be expected that the low societal acceptance of coal will lead to a further loss of regulation advantage for clean coal technologies.

China

Historical development of "clean coal policy"

Subcritical coal power plants dominated in China until 2000. Whereas significant supercritical technologies are observable only from beginning of 2004, the installation of ultra-supercritical capacities began in 2007. Historically, the decade from **1970-1980** is characterized by inefficiencies of the innovation system (see Fuchs et al. 2011): A strict state control on innovation activities was accompanied by low R&D spending. In absence of environmental regulation measures exclusively subcritical technologies have been used. Furthermore, some plants with Circulated Fluidized Bed Combustion (CFBC) with low efficiency but allowing to burn cheap coal were constructed.

From **1980-1990** the Chinese economy grew by 15% per year, first considerable foreign direct investment was observed. This decade also showed first measures to protect the environment: 1984 Pollution Prevention and Control Law, 1987 Air Pollution Prevention and Control Law, 1989 Environmental Protection Law of the People's Republic of China (see Fuchs et al. 2011). The Chinese government tried to promote high technology innovation activities: National High Technology Research and Development Program und the Torch Program (high and emerging technology industry development program) but the lack of protection of knowledge in China led to low incentives for foreign investors to use new technologies, furthermore the overall spending in R&D was still low. Furthermore, state-regulated low electricity prices reduced the incentives to invest in clean coal technologies (see Fuchs et al. 2011).

During **1990-2000** the national innovation system was strengthened by the National Basic Research program: promotion of research in agriculture, energy, environmental issues, information and communication technologies. China introduced a law for the electricity sector to trigger investments and higher emission limits for power plants but they were still significantly lower compared to other countries. A further aim was the increase of energy efficiency: Law of the People's Republic of China on Conserving Energy.

Concerning coal technologies, China promoted FBC technologies and also IGCC. Joint ventures (e.g. Dongfang and Hitachi Company (Japan), Shanghai Electric and Siemens) and license contracts Harbin and Pyro-Power Company, Dongfang and Foster&Wheeler aimed at improving the technological performance of Chinese coal fired power plants. Furthermore, a closer cooperation between Japan and China for the construction of power plants has been realized. In 1992, first supercritical power plants were constructed.

During **2000-2011** the high energy demand in connection with higher energy prices increased the pressure to develop more efficient power plants. The 11th five-year-plan contained the goal of a reduction of energy consumption per unit of GDP by 20% to increase energy efficiency. Concerning technology, the medium and long term energy conservation plan intended to use more FDC technologies and heat-power combinations and an increase of R&D in IGCC technologies. During this decade, China became a member of WTO, foreign direct investment and foreign R&D in China has been enlarged significantly (see Fuchs et al. 2011).

Assessment of the regulation advantage for clean coal technologies in China

The general policy conditions for the use of coal power plants in China are – against the background of a still highly growing energy demand – favorable, despite a growing consciousness of politicians and population for environmental measures. Following Hong et al. (2009), China has tightened its environmental protection laws and standards during the recent years. Environmental protection in the power industry is mainly carried out through the State Electricity Regulation Commission. "At the end of 2001 China's State Environmental Protection Administration initiated the national 10th Five-Year Plan for Environmental Protection to address the grim situation of environmental protection in China. The plan proposed energy-conservation and emission-reduction goals specifying that by 2005 sulphur dioxide emissions from the power industry would be reduced by 10 to 20 per cent from 2000 levels and the average coal consumption of coal-fired power plants would drop to 15 to 20 grams per kilowatt-hour below 2000 levels." (Hong et al., 2009:20).

The 11th Five-Year Plan of the Chinese government aims at restructuring the energy sector by shutting down high polluting and energy-consuming small thermal power plants: "In 2007 the State Council proposed the closure of 50 gigawatts of thermal power units during the period of the 11th Five-Year Plan, replacing them with the installed capacity of larger and more energy-saving superscale or ultra-superscale thermal power units. This means that 12 gigawatts to 13 gigawatts will be closed down annually." (Hong et al., 2009:22).

The industrial policy of the Chinese government aims at increasing the energy efficiency in energy-intensive sectors such as steel and electrolytic aluminum industries " … in order to substantially lift entry barriers in terms of energy efficiency and to speed up the elimination of small steel-making and thermal power." (Hong et al., 2009:22). In Article 31 of the law on Energy Conservation, "…the state encourages industrial enterprises to adopt highly efficient and energy-saving motors, boilers, furnaces, fans and pumps, and to employ co-generation technology, residual heating and pressure utilization, clean coal technology and advanced energy monitoring and control technologies." (Hong et al., 2009:20). In fact, from 2001 to 2011, 21 ultra-supercritical coal-fired power plants were constructed in China.

To sum up, in China, the regulation situation seems to be positive for the implementation of clean coal technologies. On the one hand, because of the high and still growing energy demand connected with enormous coal reserves, China will not renounce the use of coal. On the other hand, a growing environmental consciousness of politicians and parts of the population trigger the development of cleaner coal technologies. The construction of ultra-supercritical coal-fired power plants during the last years confirms this argumentation.

Japan

Historical development

In the early 1970s Japan had a quite one-sided alignment towards oil. After the oil crises in 1973 and 1979, a more balanced energy mix was developed. The "Law concerning Rational Use if Energy" was passed and R&D expenditure for coal increased obviously, for example coal liquefaction (see Fuchs et al. 2011).

The "Alternative Energy Law" was passed to promote alternative energy sources for oil and a prohibition for building oil power plants. Central elements of R&D was circulating fluidized bed combustion, pressurized fluidized bed combustion and the development of power plants with ultra-supercritical steam parameters to lower costs and raise efficiency (see Fuchs et al. 2011).

In 1995, the first "Science and Technology Basic Law" was adopted and specified by the "Science and Technology Basic Plan". Japan also began to liberalize its energy market. One year later a voluntary agreement to lower CO_2 emissions was enacted, inter alia "The Federation of Electric Power Companies of Japan" concluded to lower the CO_2 emissions per unit of output about 20%. Several possibilities to achieve this goal were mentioned: more nuclear power plants, a raise of efficiency of power plants and the use of new techniques (renewable energy). Research still focused on fluidized bed combustion and IGCC technology (see Fuchs et al. 2011).

In 2001 and 2006, new Science and Technology Basic Plans were established. The "Basic Energy Plan" and "Strategic Energy Plan" aim among other things for a reduction of dependence on imports and a raise of CO_2-free energy production to over 70%. For this purpose, an obvious reduction of CO_2 emissions of new coal power plants was planned. Furthermore, Japan proceeded with liberalizing their energy market and continued research in the IGCC technology sector (see Fuchs et al. 2011).

After the catastrophe of Fukushima in 2011 there was nearly no social acceptance for nuclear energy (Meltzer 2011). To close the gap left behind by nuclear power plants Japan is forced to raise the amount of coal and especially oil/gas power which will lead to increased costs of imports. Currently Japan is working out a new energy concept (see Hünteler et al., 2012).

Assessment of the regulation advantage for clean coal technologies in Japan

Especially the Japanese innovation policy seems to be favorable for the development of clean coal technologies because of the focus on highly efficient power plants. The R&D subsidies are high and co-operations between universities and the industry are actively supported. The relatively high amount of ultra-supercritical power plants constructed during the last twenty years confirms this picture. In fact, Japan is forced to develop and use highly efficient coal technologies because the country is highly dependent on imports of energy. On the other side, the Japanese energy firms are strongly export oriented so that they are forced to develop new and efficient technologies that may be sold on the world market.

In future, against the background of the high risk of nuclear power plants in Japan, efficient clean coal technologies may still play a more important role.

USA

Historical development

In the 70ies subcritical power plants dominated, but, interestingly, in 1959/1960 the USA constructed the first ultra-supercritical coal-fired power plant but abandoned this technology nearly completely. First measures to reduce the dependence from oil reserves took place, e.g. the Public Utility Regulatory Policies Act promoting renewable energy and opening electricity markets, and the Energy Tax Act reducing charges for solar, wind and geothermal heat. The use of oil and gas in the industrial sector was limited by an enlargement of R&D for the energy sector, by promoting of PFBC allowing for higher efficiency and the by use of low-quality coal (see Fuchs et al. 2011).

In the 80ies, under the Reagan-Government, deregulation and a reduction of public R&D started. A Clean Coal Technology Program was introduced due to the discussion of acid rain.

The policy continued in the 90ies with the Energy Policy Act of 1992. This led to a further opening of the electricity market leading to an increase of the construction of gas-fired power plants due to their low investment costs and due to generally low gas prices and high reserves of gas in the USA (see Fuchs et al. 2011).

During the past decade oil prices increased drastically, and a Climate Change Technology Program (CCPT) was introduced: The goal is to reduce greenhouse gas emissions and to further develop clean coal technologies such as IGCC and CCS, new nuclear power plants and more renewable energy. The Clean Coal Power Initiative (CCPI) developed and commercialized new coal technologies, especially CCS and IGCC (see Fuchs et al. 2011).

Today, the USA experiences a new natural gas boom. One reason consists in the new environmental targets of less CO_2 emissions. The combustion of natural gas emits less CO_2 and SO_2. Combined cycle power plants only emit the half compared to an equivalent coal power plant. The second reason is the increasing gas supply in the USA accompanied by decreasing prizes. Due to the hydraulic fracturing technology, unconventional new resources that were not profitable up to now, can be extracted (Energy in Brief, 2012). So it has been estimated that 500 coal power plants can be replaced by new natural gas power plants (Handelsblatt, 2011).

Assessment of the regulation advantage for clean coal technologies in USA

The development of efficient energy technologies is mainly market-driven, there is only few public R&D support. Concerning coal technologies, the USA show a concentration on IGCC and Fluidized Bed Combustion. Despite the fact that the first ultra-supercritical power plant was constructed in the USA in 1959, this country abandoned this technology. Furthermore, the environmental policy regarding a CO_2 emission reduction strategy is quite lax. In fact, there seems to be no regulation advantage for the USA concerning clean coal technologies.

To sum up, compared to the US, Germany and Japan, China seems to have a regulation advantage concerning clean coal technologies.

5 Market structure, lead suppliers and technological capability

The recent literature on lead markets (e.g. Rennings and Cleff 2011 or Tiwari and Herstatt 2011) accentuates the role and the importance of supply side aspects for the developments of lead markets. A competitive market structure combined with the existence of highly innovative lead suppliers may be the basis of the leadership of a country in a specific technology. Therefore, we firstly analyse the market structure for coal technologies combined with an identification of the respective lead suppliers. Secondly, we analyse the framework conditions for competition and innovation in our four countries followed by a deeper analysis of the technology capabilities using patent indicators.

The question which market structure is best for the realization of innovations has a long tradition in the theoretical literature on innovation behaviour of firms. Following Arrow (1962), firms in competitive markets have higher incentives to invest in R&D because they may get – at least for a limited period of time - the full economic rent from an innovation. Contrary to that, Schumpeter (1943) argues that big firms in monopolistic markets are more likely to solve the appropriation problem, namely to keep the rents of their innovation. Therefore, the role of the market structure remains an empirical question. Many empirical analyses support the view of Arrow, but especially the more capital intensive the industry and the respective innovation activities, large firms in monopolistic markets may also be more innovative (see Martin 2006).

Concerning coal technologies, the markets in our four countries seem to be highly concentrated. Table 3 shows the shares of the “big five” producers of whole components, turbine and boiler suppliers. Following this indicator, the markets in Japan and the USA are characterized by the highest concentration whereas the situation in Germany seems to be a bit more competitive.

Table 3: Number of clean coal technology suppliers

Country	Producers of coal power plants		Turbine suppliers		Boiler Suppliers	
	Number	Share* of "big five" in %	Number	Share* of "big five" in %	Number	Share* of "big five" in %
China	23	81	27	83	22	80
Germany	17	71	18	87	19	63
Japan	6	99	7	99	6	99
USA	20	96	12	95	20	96

* Related to the number of plants.
Please note that the IEA Coal database contains many missing values concerning the names of the producers. The "shares of the big five" are calculated without missing values implicitly assuming that the plants without producer information show the same distribution.

Source: IEA (2011a).

The Lead Suppliers (number of constructed plants in brackets) in the different countries are as follows:

China:

Shanghai Boiler Works Company (330), Harbin Power Engineering (294), *Shanghai Electric Corporation (243)*, Dongfang Electric Corporation (222), Wuhan Boiler Works (103)

Germany:

Hitachi Power Europe (44), *Shanghai Electric Corporation (39)*, L. und C. Steinmüller GmbH (22), EVT Energie und Verfahrenstechnik GmbH (16), Dampferzeugerbau Berlin (15)

Japan:

Mitsubishi Heavy Industries (29), Babcock Hitachi KK (19), Ishikawajima-Harima Heavy Industries (17), *Shanghai Electric Corporation (12)*, Kawasaki Heavy Industries (5)

USA:

ABB Combustion Engineering (393), Babcock and Wilcox (358), Foster Wheeler (122), *Shanghai Electric Corporation (118)*, Riley Stoker Corporation (93)

Interestingly, the Chinese company "*Shanghai Electric Corporation*" constructs power plants in all of the considered countries showing the rising importance of China for coal technologies.

On the background of the above mentioned controversial theoretical debate and the fact that the development and the construction of new clean coal based power plants is capital intensive the identification of a market structure advantage of any of the four countries is - following our concentration indicator - not possible.

Therefore, it is furthermore useful to explore the general competition conditions in the four countries on the basis on the Global Competitiveness Report of 2011. This report contains a rich set of indicators on innovation and the respective framework conditions (see Table 4).

The overall Global Competitiveness Index (GCI) shows the highest rank for the USA (5) followed by Germany (6) and Japan (9). China already reaches rank 26. To assess the conditions for the development of new (clean coal) technologies it is more interesting to look at subgroups of the GCI especially on innovation indicators and those that describe the efficiency of the goods market.

The innovation indicators show a dominant role of Japan: First ranks on the capacity of innovation, company spending on R&D and a second rank for the availability of scientists and engineers seeming to be a problem for Germany only reaching the last rank of the four countries (41). Concerning the patents granted (2), the state of the cluster development (3) and for the firm-level technology absorption (3) Japan also attains the highest values of the four countries. Besides variables on trade barriers and rules on FDI, Japan shows high values for the variables on good market efficiency, too. The intensity of local competition (rank 4) and the effectiveness of anti-monopoly policy (rank 9) also seem to be very high in Japan.

The USA also reaches high ranks but mostly behind Japan except e.g. the quality of scientific research institutions (rank 7), the government procurement of advanced technical products (9, the availability of latest technologies (13) and the venture capital availability (12).

Germany also shows high innovation capacities (3) and a high quality of scientific research institutions (10). Comparing the four countries, Germany reaches the best positions regarding the quality of the educational system (17), the quality of the overall infrastructure (10) and the intellectual property protection (13). Concerning this indicator, China only attains a low rank (47). That is also the case for the effectiveness of anti-monopoly policy (48) and especially for the existence of bureaucratic barriers in this country measured by the number of procedures to start a business (131). Compared to the other three countries, the innovation capacities in China still seem to be quite low.

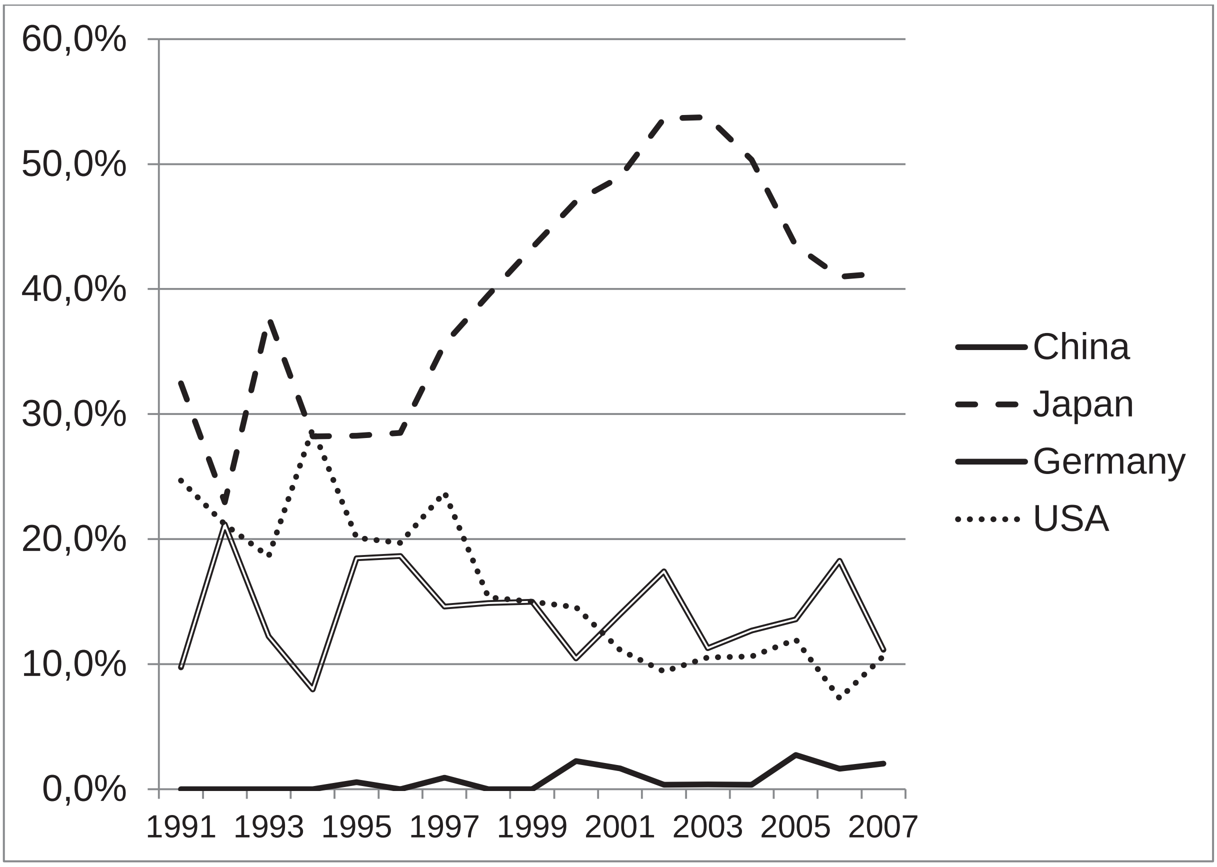
Table 4: Indicators from the Global Competitiveness Report

Indicator	China		Germany		Japan		USA	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank
GCI 2011-2012	4.9	26	5.4	6	5.4	9	5.4	5
Good market efficiency								
Intensity of local competition	5.5	22	5.8	9	5.9	4	5.6	18
Extent of market dominance	4.7	20	5.7	3	5.8	2	5.2	11
Effectiveness of anti-monopoly policy	4.3	48	4.9	23	5.2	9	5.0	17
No. of procedures to start a business	14	131	9	94	8	78	6	34
Prevalence of trade barriers	4.5	63	4.7	49	4.1	100	4.6	59
Business impact of rules on FDI	5.3	22	4.6	72	4.5	87	4.7	68
Innovation indicators								
Capacity for innovation	4.2	23	5.7	3	5.8	1	5.2	7
Quality of scientific research institutions	4.3	38	5.6	10	5.5	11	5.8	7
Company spending on R&D	4.2	23	5.5	5	5.9	1	5.3	6
University-industry collaboration in R&D	4.5	29	5.2	13	5.1	16	5.7	3
Gov´t procurement of advanced technical products	4.4	16	4.2	29	4.1	32	4.7	9
Availability of scientists and engi-	4.6	33	4.5	41	5.8	2	5.5	4
neers	2.0	46	150.6	9	352.9	2	339.4	3
Utility patents granted/mill. popu-	4.7	17	4.9	13	5.3	3	5.1	9
lation	4.5	100	6.2	20	6.3	15	6.0	13
State of cluster development	4.9	61	5.9	14	6.3	3	5.9	18
Availability of latest technologies	4.6	80	4.3	92	4.7	65	4.9	49
Firm-level technology absorption	3.5	22	3.0	37	2.9	47	4.0	12
FDI and technology transfer								
Venture capital availability								
Further indicators	4.0	54	4.9	17	4.4	36	4.7	26
	4.2	69	6.2	10	6.0	13	5.7	24
Quality of the educational system	5.5	49	6.7	11	6.5	17	6.0	32
Quality of overall infrastructure	4.0	47	5.6	13	5.3	22	5.0	28
Quality of electricity supply	3.9	21	3.0	88	3.2	73	3.4	58
Intellectual property protection	4.7	41	5.0	28	4.8	38	4.5	50
Burden of government regulation	5.0	77	5.0	77	7.0	16	8.3	5
Transparency of government policy								
Strength of investor protection								

Source: World Economic Forum (2011).

The technological capabilities of the different countries with respect to coal technologies can be measured by the importance of the respective patent activities. Figure 17 shows the world market shares of coal fired power plant technologies in the four countries documenting the high technology capabilities of Japan with a share of 40% in 2007. In the USA, the market share declined from 1991 to 2007 showing the diminishing interest and capability of this country in the development of clean coal technologies. In Germany, the patent shares are stagnating whereas the figures for China are rising but starting at a very low level.

Figure 17: World Market Share Patents: Coal-fired Power Plant Technologies



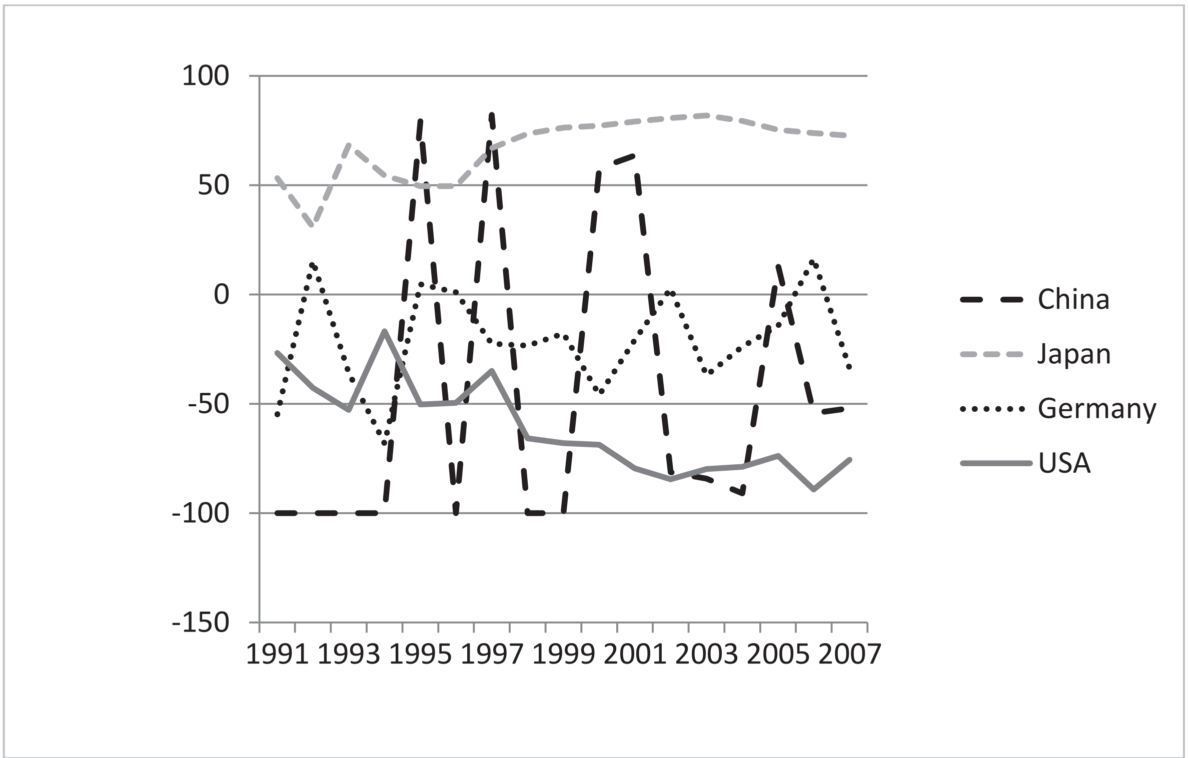
Source: ISI (2012).

Furthermore, the Relative Patent Advantage is calculated for each country *i* and each technology field *j* according to (see Walz and Marscheider-Weidemann (2011)):

$$RPA_{ij} = 100 * \tanh \ln\{(p_{ij}/\sum_i p_{ij})/(\sum_j p_{ij}/\sum_{ij} p_{ij})\}$$

The RPA indicates if the world patent share of clean coal technologies of a country is bigger or smaller than the country´s world patent share for all technologies.
The RPA values confirm the picture obtained for the world patent shares (see Figure 18).

Figure 18: Relative Patent Advantage for Coal-fired Power Plant Technologies



Source: ISI (2012).

For all years from 1991 to 2007, only Japan shows positive figures documenting its leading technological capabilities for clean coal technologies. The RPA values also confirm the decline of the importance of coal technologies for the USA. Because of low absolute values for the number of coal related patents the figures for China do not yet show a clear picture. The stagnating situation for Germany regarding clean coal technology capabilities is confirmed.

To sum up, all countries are characterized by high concentration values for coal technology suppliers so that further indicators have to be analysed to assess a market structure advantage. Once again, Japan seems to be on top of the four countries because of its high innovation capacities and the high availability of scientists and engineers.

6 Firm views and strategies – results from expert interviews

To analyze the strategies of firms regarding the development and use of new efficient coal technologies against the background of a growing political support of renewables expert interviews were carried out. A producer of components for coal based power plants (Saarschmiede), a power plant producer (Hitachi Power Europe) and an energy supplier (Vattenfall) were interviewed.

The expert interviews aimed at analyzing

- the existence and the role of first mover advantages concerning efficient coal technologies including the countries China, Germany, Japan and the USA;
- how component suppliers, power plant producers and energy suppliers react to energy policy changes especially in Germany.

Presentation of the questioned firms

Saarschmiede produces components for (coal fired) power plants (e. g. turbine & generator shafts, turbine & compressor rings, parts for plant construction or high pressure vessels). Germany remains the main market (37%) followed by Europe (23%), Asia (23%) and the USA (15%). Whereas the construction of completely new power plants plays an important role in China and India, in Germany and especially in the USA, the refurbishment of existing power plants dominate. The Saarschmiede may be characterized as one of the world market leaders regarding high quality steel components for power plants, the main competitors are coming from Japan (Japan Steel Works, Japan Casting and Forging Corporation) or from Europe (Böhler, Germany or Terni Steel, Italy) whereas competitors from the USA do not play an important role. The main customers in Europe are Siemens, Alstom or GE but the Chinese market gains importance (Shanghai Boiler Works, Harbin Power Engineering or Dongfang Electric Corporation as clients of Saarschmiede).

Hitachi Power Europe is one of the main constructors of fossil fired power plants (especially coal fired and nuclear based power plants). Whereas the rapidly growing market of China is supplied by other firms of the Hitachi group, Hitachi Power Europe concentrates on the construction of new power plants in Europe (especially Poland, Turkey and Russia), India and

South-Africa. In Germany, the company increasingly concentrates on services and refurbishment for existing power plants because, at the moment, nearly no new coal fired power plant projects are planned. The main competitors concerning boilers are Alstom and IHI and Siemens with regard to turbines.

Vattenfall is an energy supplier mainly producing electricity by lignite (80%). Concerning electricity production, Vattenfall has a market share of 16% in Germany. The main competitors are RWE, EON and EnBW. The main constructors of the power plants of Vattenfall are Hitachi Power Europe, Alstom and Siemens.

Market development in Germany, China, Japan and the USA

At present, the market for (clean) coal technologies in Germany is negatively assessed because of the high political support of renewables in combination with uncertainties concerning the future role of coal technologies. Nevertheless, the experts of Hitachi and Vattenfall are optimistic that coal technologies will play even a growing role to assure the energy supply in Germany, especially by the use of lignite based highly efficient power plants. At the moment, only refurbishment of existing coal power plants and services are important business areas whereas nearly no new projects are realized. In Japan, the future role of nuclear power is uncertain, but the experts do not expect a dynamic development concerning coal fired power plants. The market in China is very dynamic, around 50 new power plants are built every year leading to extensive possibilities to implement highly efficient technologies (ultra-supercritical). In the USA, at present, only few new coal fired power plants are constructed because of the high availability of gas but the high age of coal fired power plants (see Section 4.2) leads to high refurbishment potentials and markets.

Future dominating efficient coal technologies

Super and ultra-supercritical technologies will dominate other coal based technologies such as fluidized bed combustion, the future of advanced ultra-supercritical (700°C power plants) is unclear because of high investment costs and technology risks. Especially in Germany, lignite drying will be useful to increase efficiency of lignite based power plants. In the distant future Carbon Capture Storage (CCS) may play an important role but this development is strongly dependent on CO_2 prices and societal acceptance.

Assessment of the role of China as supplier

Following our analysis in Section 4.3, Japan and Germany still dominate the markets and the international trade for turbines, but concerning boilers China shows the highest export volume. According to our expert interviews, this picture is not totally true: China is specialized in low and middle temperature boilers, whereas the Chinese producers have still problems to produce high quality boilers. Even components supplied to German power plant producers have to be repaired and improved before they may be used. One expert assesses that China will be able to reduce their quality gap concerning boilers – an argument that may be confirmed by the Benson Boiler reference list of Siemens showing that Chinese firms (e. g. Dongfang Boiler Works) are able to produce boilers that are resistant to steam temperatures of more than 600 °C. Interestingly, following the new five-year-plan, China has decided to build a 700°C power plant. If this strategy will be successful, China would probably get the technological leadership. In fact, this seems to be highly uncertain because the Chinese innovation system is predominantly characterized by imitations and less by totally new technologies and products.

Concerning lignite based power plants, China is still not competitive, Hitachi and Alstom are market leaders.

Competition situation of coal technologies in Germany

Disregarding the negative external effects caused by the emissions of coal-based electricity production coal would be the cheapest solution among all energy carriers because of its reasonable cost of production and the high security of supply. The energy policy in Germany tries to internalize these negative external effects by taxes and emission permits (see also Section 4.5). Furthermore, renewable energies are highly subsidized. Nevertheless, the representatives of Hitachi and Vattenfall are optimistic that coal and especially lignite will play an important role in Germany at least up to 2050. Saarschmiede points to a growing importance to gas based electricity production.

Relevance of first mover advantages

Japan and Germany seem to have clear first mover advantages concerning the highly innovative parts of clean coal technologies and in general for 600 °C power plants whereas China has second mover advantages in manufacturing boilers. Following the experts, Germany has highly profited from these first mover advantages in terms of export success and technological leadership. The crucial question remains if the German firms are able to keep the first mover benefits against the background of the shrinking importance of coal technologies in Germany? Saarschmiede as a component producer is at least optimistic that the R&D units ("innovative cells") will not leave Germany or Japan despite of declining markets in these countries because of the lack of highly educated and innovative staff in China.

The experts of Hitachi and Vattenfall are more pessimistic. Germany and also Japan may lose their first mover advantages because a considerable part of innovation activities occurs when a power plant is constructed in close cooperation with the client. Due to the fact that nearly no new coal-fired power plants are projected in Germany, this country may lose a part of these first mover advantages. On the other side, the high market volume in China (nearly 50 power plants per year) leads to more innovation activities in this country. It is unclear if Chinese firms will be able to build a 700 °C power plant as intended in the five-year-plan but they will gain experiences and may get a technological leadership.

Following the opinion of Vattenfall, Germany will not lose its first mover advantages regarding lignite-based power plants.

An important pre-condition for keeping the technological leadership for efficient coal technologies would be the reduction of the high uncertainty regarding the future use of coal, whereas - on the other side - the profits for renewables are guaranteed. Following one expert, there is also a lack of qualified staff (engineers), an enlargement of cooperation with universities would be useful.

Strategic reactions of firms against the background of energy policy and the low societal acceptance of coal in Germany

Following the opinion of the questioned experts, the market situation in Germany for clean coal technologies requires far-reaching changes of firm strategies. For Saarschmiede, an increasing concentration on foreign markets is necessary because of the uncertainty regarding coal power plants in Germany, the firm will more and more concentrate on the Chinese market. At present, Hitachi Power Europe extends its business fields services, the refurbishment of existing power plants or the de-construction of nuclear power plants because, in Germany, the construction of new coal power plants will only be relevant in 5-10 years. Furthermore, the firm extends its activities in new markets such as Poland, Turkey or Romania whereas the Chinese market is not possible for Hitachi Power Europe. Despite these activities, Hitachi was forced to cut jobs.

On the one hand, Vattenfall will extend the use of renewable energies, on the other hand, the firm will still rely on lignite because under the condition of current and expected CO_2 prices this energy carrier will be competitive. A further option is the extension of R&D for CCS.

7 Summary and conclusions

Despite the high CO_2 emission intensity of fossil and especially coal fired energy production, these energy carriers will play an important role during the coming decades. The case study identifies the main technological trajectories concerning more efficient fossil fuel combustion and explores the potentials for lead markets for these technologies in China, Germany, Japan and the USA taking into account the different regulation schemes in these countries. We concentrate on technologies that have already left the demonstration phase. This is the case for supercritical (SC) and ultra-supercritical (USC) pulverized coal technologies that are already established.

An analysis of the diffusion of efficient coal technologies shows that the USA took over the role of a lead market in the 1960's and during the following 20 years. Other countries followed the American innovation design, such as Germany in the 1960's and Japan in the 1970's. The diffusion curves overlap by Japan in the early 1980's since America stopped to build new (ultra-) supercritical power plants. Although China is still the last country that introduced ultra-supercritical technologies in 2007, commercial adoption of this technology is expanding rapidly. The analysis shows that the typical pattern of a stable lead market only applies to a limited extent because Japan has surpassed the USA although it started as a typical lag market.

In a second step, we analyze the different lead market factors. The *price advantage* is described by hard and brown coal reserves, fuel prices and electricity generating costs. The USA and China show a clear price advantage regarding the coal reserves. Furthermore, China has the lowest generating costs so that, all in all, China seems to have the best position regarding the price advantage whereas Japan holds the last position because of the lack of reserves and high prices. High income per capita in the USA, Japan and Germany point to a *demand advantage* of these countries but high electricity intensity and the highest share of coal in electricity production (80%) favors China. The USA shows the highest average age of coal plants pointing to refurbishment potentials. To describe the *export advantage* the indicators "export minus import" and the "development of export/import ratio" has been used. China seems to have an export advantage for steam boilers, whereas Japan holds this position for steam turbines. Due to the growing importance of highly efficient coal power plants requiring "high-tech" steam boilers, the Chinese producers will only keep their export advantage if they are able to improve the technical quality of their boilers.

On the one hand, the *transfer advantage* describes the capability of a country to be or to become a lead market in the respective technology. On the other hand, but closely correlated to the capability, a country shows a high transfer advantage if the international reputation and attention regarding the specific technology is high. To measure the transfer advantage for efficient coal technologies, we use the indicators "degree to which R&D matters in a country", "R&D related to coal technologies and CCS (Carbon Capture Storage)", "number of demonstration plants in a country" and the "efficiency of coal fired power plants". The results for our indicators show a clear transfer advantage for Japan. The average efficiency of coal-fired power plants is the highest, furthermore Japan is characterized by the highest number of demonstration plants and percentage of R&D in general and also related to coal technologies.

Germany lost much of its *regulation advantage* for clean coal technologies during the last ten years because of a clear cut change of paradigm towards renewables. It may be true that this new strategy also triggers the development of more efficient coal technologies but on the other hand the coal sector lost much of its financial support by the state in favor of renewables. In the long run, it can be expected that the low societal acceptance of coal will lead to a further loss of regulation advantage for clean coal technologies. On the other hand, in China, the regulation situation seems to be positive for the implementation of clean coal technologies. Chinese politicians will not renounce the use of coal because of the high and still growing energy demand connected with enormous coal reserves. Furthermore, a growing environmental consciousness of politicians and parts of the population triggers the development of cleaner coal technologies. Compared to the US, Germany and Japan, China seems to have a regulation advantage concerning clean coal technologies.

The analysis of *supply side factors* shows that all countries are characterized by high concentration values for coal technology suppliers. To assess a market structure advantage, further indicators have to be analysed. Japan seems to be on top of the four countries because of its high innovation capacities and the high availability of scientists and engineers and because of its leadership regarding clean coal patent activities.

All in all, Japan has caught up in terms of supply factors, China in terms of price, demand and regulation advantage. The fact that Japan is now the leading country for ultra-supercritical coal technologies supports the hypothesis that - apart from the demand-oriented lead market model - push factors such as R&D activity play a strong role as well. The advantage of Japan mainly stems from its intensive R&D activities. It can also be observed that some other advantages - such as price and demand advantage - are shifting to China. China is practicing a leapfrogging strategy, and has already become a leader in the market segment of low and middle quality boilers, whereas Japan and Germany still dominate the world turbine market.

To learn more about the reactions of firms towards a changing energy policy favoring renewables expert interviews were carried out. These interviews confirm that Japan and Germany seem to have clear first mover advantages concerning the highly innovative parts of clean coal technologies and in general for 600 °C power plants whereas China has second mover advantages in manufacturing boilers. The crucial question remains if the German firms are able to keep the first mover benefits against the background of the shrinking importance of coal technologies in Germany? Saarschmiede as a component producer is at least optimistic that the R&D units ("innovative cells") will not leave Germany or Japan despite of declining markets in these countries because of the lack of highly educated and innovative staff in China.

The experts of Hitachi and Vattenfall are more pessimistic. Germany and also Japan may lose their first mover advantages because a considerable part of innovation activities occurs when a power plant is constructed in close cooperation with the client. Due to the fact that nearly no new coal-fired power plants are projected in Germany, this country may lose a part of these first mover advantages.

Following the opinion of the questioned experts, the market situation in Germany for clean coal technologies requires far-reaching changes of firm strategies. For Saarschmiede, an increasing concentration on foreign markets is necessary because of the uncertainty regarding coal power plants in Germany, the firm will more and more concentrate on the Chinese market. At present, Hitachi Power Europe extends its business fields services, the refurbishment of existing power plants or the de-construction of nuclear power plants because, in Germany, the construction of new coal power plants will only be relevant in 5-10 years. Furthermore, the firm extends its activities in new markets such as Poland, Turkey or Romania. On the one hand, Vattenfall will extend the use of renewable energies, on the other hand, the firm will still rely on lignite because under the condition of current and expected CO_2 prices this energy carrier will be competitive.

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The Dutch sunrise: Catalyzing solar energy market growth by creating shared value business models

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1. Introduction

Considering the problems we face with our current energy system, like uneven distribution of resources, climate change and pollution, the need for a transition toward a more sustainable system is highly pressing. Of all renewable energy options, solar energy or PhotoVoltaics (PV) is the most promising. It is available everywhere, is a proven technology and has the largest potential of all renewable energy sources (EPIA and Greenpeace, 2011). Over the last decade the PV market started to show exponential growth resulting in a globally installed capacity of 69 GW in 2011 of which 51 GW could be attributed to the European Union (EPIA, 2012). This was mainly driven by favorable governmental support mechanisms (i.e. Feed-in-Tariffs) in countries like Germany and Italy (Schleicher-Tappeser, 2012; Timilsina et al., 2012). This has lead to a dramatic surge in production capacity, mainly in China. Accordingly, prices went down from more than $4 per Wp in 2008 to less than $1 per Wp in January 2012 (Aanesen et al., 2012). However, this has put high pressure on profit margins of PV module producers leading to a major shakeout in industry which was further worsened by the economic crisis which lead to subsidy cuts in many countries. From 2009 onwards venture capital was therefore increasingly invested in downstream business models rather than in low profit margin module producers (Aanesen et al., 2012).

Transitions are major changes in socio-technical systems in society, like energy supply or mobility (Geels and Schot, 2010). Novel sustainable technologies, like PV, emerge in protected spaces called niches where new socio-technical constellations are tested in experiments from where they can be scaled up to viable commercial activities in the mainstream market environment. Recently, a number of transition scholars also started to explore the role of business model experiments in niches and their potential for wider up scaling (Huijben and Verbong, 2013). Huijben and Verbong (2013) have analyzed a set of PV business model experiments in the Netherlands using both business model and transition studies literature. Surrounded by PV champions like Germany and Belgium with high levels of governmental support, the Netherlands has shown a poor track record in installed PV capacity over the last decade (Huijben and Verbong, 2013). This was mainly caused by weak and unstable support of the Dutch government. However, from 2008 onwards many new initiatives were started, though absolute numbers are still low. For 2011, total installed capacity was 130 MW (CBS, 2012). This number doubled for 2012 (KEMA, 2013). Decreasing PV prices and favorable, but unstable and contested net metering regulations were main drivers for this. Additionally, a number of new business models for PV, aiming at households and SMEs, were developed taking issues like high up-front investment and perceived technological and economical risks into account. Large companies pay too little per kWh of conventional electricity for PV to be able to compete with. These business models were categorized in three main groups: Collective buying, Community Shares and Third Party. The first was found to be by far the largest. Both at local and national level citizens are joining together in buying PV systems. Community Shares business models, where households can buy a share in a project at a central location, is still in an experimental phase because of the need for approval of so-called off-site or virtual net metering legislation. Finally, third party business models, where an external party makes the investment in a PV system are up coming, both for households and SMEs. However, these business models are fairly complex because of the needed contracts between the investor and the owner of the building. In some cases it also requires changes in legislation. Additionally, the authors found the overall PV niche to be maturing, as organizations at both local and national level were started for knowledge sharing, networking and lobbying towards the national government. Thus, the emergence of new business models was crucial for the PV market development in the Netherlands, but was part of broader niche development processes that were ongoing. However, research on the topic of the interaction between business models and the wider socio-technical system they are connected to needs further research (Boons and Lüdeke-Freud, 2012; Huijben and Verbong, 2013; Loorbach and Wijsman, 2012).

Interestingly, a number of SMEs and large companies that were previously unrelated to the Dutch energy or PV market started to link to these developments, either as being the customer target group of a PV business model or by actively helping to develop PV business models for other customer segments. Thereby, these companies are internalizing the issue of development of a sustainable energy system into their business operations. This is done because it is believed to be of direct value for the company itself as well. Thus, value is created for multiple stakeholders simultaneously. This is also known as Creating Shared Value (CSV) (Porter and Kramer, 2011). It requires the development of a ‘business case for sustainability’ which “*results from the intelligent design of voluntary or mainly voluntary social and environmental management and creates a positive effect based on a distinct* *management or entrepreneurial activity"* (Schaltegger and Lüdeke-Freund, 2012, pp 2). Additionally, a certain degree of business model innovation is needed as well (Schaltegger et al., 2012). Another example of CSV is the investment of the German car manufacturer Audi in electricity storage technology for renewable energy sources like wind or solar which they want to use for making their manufacturing process carbon neutral (Bockstette, 2011). This is not only in favor of the company itself but also important for the further development of the renewable energy sector in Germany. Bockstette (2011) refers to this as a *"trampoline approach"* (Bockstette, 2011, pp 1). Thus, while doing well for their company (i.e. increasing profits), companies can make a contribution to societal change as well. This is in line with the concept of *"Catalytic Philanthropy"* aiming at making a structural change in society rather than making a onetime donation to charity (Kramer, 2009, pp 30). This is also acknowledged by Loorbach and Wijsman (2012) arguing that by transforming their own business companies can at the same time shape the environment they operate in (i.e. co-evolution) and shape sustainability transitions. However, their approach is focusing on changing the core market the company is operating in, not previously unrelated markets like in the Audi and Dutch PV cases described here.

With this paper I aim to contribute to the further understanding of the role of companies in socio-technical transition processes with a focus on the CSV business model as a scaling up mechanism. I will therefore analyze a set of PV CSV business model experiments in the Netherlands. These will be analyzed from both an individual firm and a transition studies perspective. How do these business models work (business model mapping)? What were the drivers for companies to adopt them? How did this influence their core business model? Additionally, how did this contribute to wider transition processes (i.e. scaling up of the Dutch PV market)? Considering business models as being part of a wider socio-technical system, what are its limitations? And, more in general, what can companies learn from taking a transition studies perspective in their CSV strategy formation? Additionally, I aim to critically reflect on the concept of CSV, especially in relation to earlier concepts of social value creation like Corporate Social Responsibility (CSR) and social entrepreneurship.

Below first an overview of literature on transitions, business models and CSV will be provided. Next, a section on methodology and data collection will be given followed by an overview of initial results. The paper will end with a discussion and conclusion section.

2. Theory

2.1 Transition Studies

Transitions are major changes in the current way of fulfilling societal needs like mobility or energy (Geels and Schot, 2010). Strategic Niche Management is part of transition literature and focuses on the development of so-called niches, where novel technologies like PV are emerging under protective conditions. New socio-technical constellations are tested in a number of 'sustainability experiments' which are *“planned initiatives that embody a highly novel socio-technical configuration likely to lead to substantial (environmental) sustain- ability gains”* (Berkhout et al., 2010: p. 262). Protection is needed to shield these from the mainstream environment which in SNM is referred to as ‘the regime’. Actor networks, action-guiding rules (regulative, normative, cognitive) and technical artifacts are together building the regime (Geels, 2005). Destabilization of the regime can lead to opportunities for niches to scale up and (partly) change the regime (Geels and Schot, 2010). However, this requires development of the niche itself as well. Three processes were found to be crucial for niche development: shaping expectations, network building and learning. In an early stage these were only assessed from an individual project perspective. However, later on it was found that these individual projects also start to form an ‘emerging community’ as they start to build on each other (Geels and Raven, 2006). Lessons from local projects are translated to more general ones and vice versa and this requires dedicated work (Raven, 2008) (figure 1).

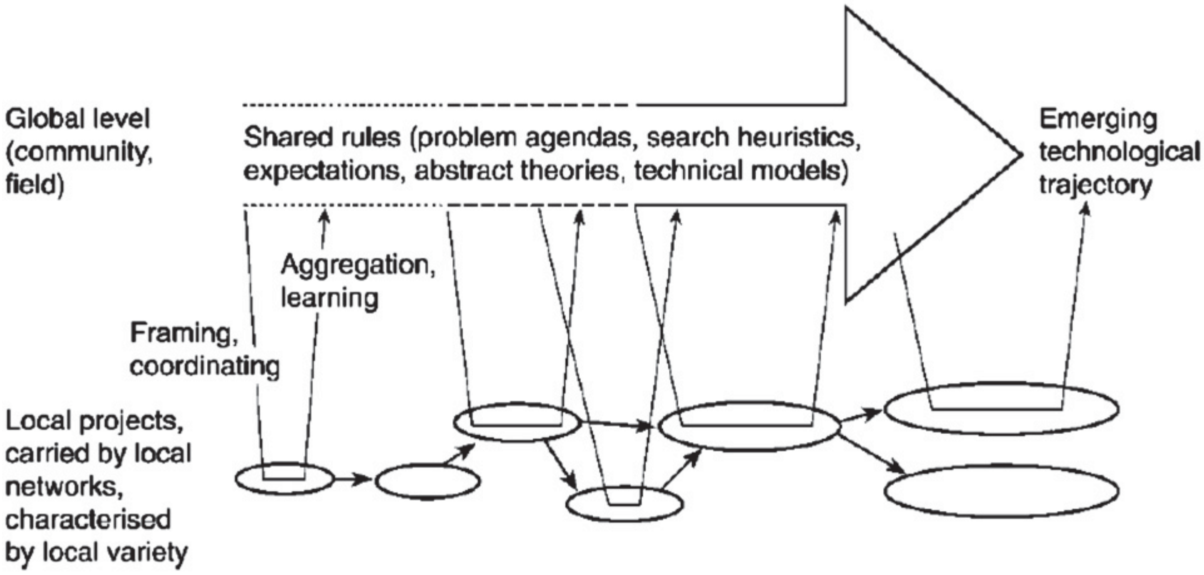

Figure 1: Development of an emerging community from local projects (taken from Raven, 2008).

Transition studies and business models

Recently a number of SNM scholars also started to explore the role of business model experiments in niches (Huijben and Verbong, 2013). By combining insights from SNM and business model literature new insights in up scaling processes were found. Business model literature is very helpful for analyzing the individual business models that are being experimented with (i.e. business model mapping). SNM on the other hand can put these into broader context by revealing existing regime barriers and analyzing broader niche development processes. The combined framework was applied to a set of PV business model experiments in the Netherlands (see also *Section 1* above). Additionally, Cheschin (2012) has examined how a specific type of sustainability business model, a so called Product Service System (PSS), can be implemented and up scaled by performing niche experiments. Such experiments can contribute to transitions by acting as a lab, window or agent of change respectively. In a PSS experiment learning on various dimensions (e.g. technological, social, political) takes place, preferably in different contexts (i.e. project as a lab). Additionally, interest is raised for the PSS innovation. Linkages with new actors and projects are formed and results are shared over projects (i.e project as a window). Finally, PSS projects can serve as agents of change by influencing contextual conditions that are necessary for up scaling of the PSS innovation. Several social groups are encouraged to change their perspectives and behavior (e.g. pushing for changes in legislation). However, research on the interaction between business models and the broader socio-technical system they are connected to is still in an early phase (Boons and Lüdeke-Freud, 2012; Huijben and Verbong, 2013; Loorbach and Wijsman, 2012).

2.2 Creating Shared Value

Over the last years companies have increasingly been blamed for causing environmental, social and economical problems leading to a gap between companies and society and a low level of trust in them (Porter and Kramer, 2011). Opportunities for addressing important social and environmental needs were missed and assumed to be solved by NGOs and governments. However, by integrating economic and social or environmental needs in their business operations corporations can contribute to sustainable development. This is known as Creating Shared Value (CSV). In this way, the company could act as a ‘honey bee’ making a living while at the same time producing many positive external effects (Elkington, 2004). Social businesses create social or environmental value while at the same time ensuring a recovery of investments in the company (Yunus, 2010). This is in contrast to CSV in the sense that companies performing CSV activities for their mere part remain profit maximizing businesses by selling their core product or service. However, CSV might be a first step in moving the company towards a more social business profile. CSV also goes beyond traditional Corporate Social Responsibility (CSR) activities which focus on dedicating part of a company’s revenues to philanthropy and which is unrelated to its core business model (Wani and Raghavan, NA). Wani and Raghavan (NA) define this as being external CSR, internal CSR on the other hand is in line with CSV. Porter and Kramer (2011) define CSR to be separate from profit maximization, pushed by external pressure and personal agendas and limited to the corporate footprint and the available budget. Thus, CSV can be considered as a new form of CSR, where integration between ‘doing good’ and the company’s core business is key. However, even when doing so, there is a limit to the number of business cases for sustainability that can be created (Schaltegger and Lüdeke-Freud, 2012). Also, in practice it is often difficult to do well while doing good, to align the different stakeholder interests and to do that for a longer time period (O’Toole and Vogel, 2011). For some social problems governmental intervention remains critical; the impact companies can make is limited. However, even when companies are not able to solve all societal problems themselves, they can still utilize their resources and skills for stimulating social progress in ways NGOs or governmental programs would not be able to do (Porter and Kramer, 2011).

Where to look for CSV opportunities

Porter and Kramer (2011) have identified a number of social issues directly related to a company's productivity which can be a source for CSV activities: environmental impact, supplier access and viability, employee skills, worker safety, employee health, water use and energy use. Additionally they distinguish three ways of CSV which are mutually reinforcing: "*reconceiving products and markets, redefining productivity in the value chain and building supportive clusters at the company's locations*" (Porter and Kramer, 2011, pp 7). First, by looking at all potential harms and benefits included in a company's product, CSV opportunities can be unraveled. This can lead to serving entirely new markets, for example in developing or emerging economies. This is a dynamic process as technology, economy and societal needs are constantly changing. Moreover, serving new market segments can lead to adaptations in more traditional markets as well. Second, a company's value chain can lead to many internal costs, caused by for example extensive use of resources, even when there is no punishing regulation in place. While previously it was believed that reducing environmental pressure could only lead to higher costs, nowadays there is consensus on the fact that it may even lead to reduced costs for the company. Porter and Kramer (2011) define four areas where CSV opportunities in the value chain can be found: energy use and logistics (e.g. buildings, transport), resource use (e.g. water, raw materials), procurement (less pressure on supplier margins so that they can get stronger and provide higher quality products), distribution systems, employee productivity (wellbeing) and location (short distance value chain and local community development). Finally, CSV can be related to the development of so-called local clusters consisting of local related companies, trade and standards associations and knowledge institutes. Clusters also rely on local commodities such as schools, fair laws and clean water. Companies working in a strong cluster will have high productivity rates, for example because of more efficient collaboration. Deficiencies in these clusters, like a low average level of education, will lead to internal costs for the companies and are therefore an opportunity for CSV. By building a supportive cluster related communities and companies will benefit directly. Partnering with other organizations is essential for cluster building (and other forms of CSV). This may even include working with competitors for creating precompetitive conditions.

Creating Shared Value and business models

As indicated in the discussion above, creating economic value for the core company is a prerequisite for CSV. Therefore, drivers for business cases for sustainability (or CSV) are essentially the same as those of normal business cases (Schaltegger et al., 2012). Based on a literature review, Schaltegger et al. (2012) have identified 6 core business case drivers: cost and cost reduction, risk and risk reduction, sales and profit margin, reputation and brand value, attractiveness as employer and innovative capabilities of the company. Business cases for sustainability can be assessed on their influence on these drivers. This is also linked to the corporate sustainability strategy of the company which can be defensive, accommodative and proactive. Based on the chosen company strategy, business case drivers are limited or fully integrated in the daily business operations of the company. For a defensive strategy business case drivers are only limited integrated. The main point is to comply with legislation and sustainability is considered from a narrow perspective. In case of an accommodative strategy business case drivers are integrated, but in a modest way. The core logic of the business is not being questioned when making adaptations for sustainability to the organization. Finally, for proactive strategies business case drivers are fully integrated and sustainability and economic goals are addressed simultaneously. Also, for addressing the various business case drivers adaptations to the company's core business model are needed. Schaltegger et al. (2012) explore what the influence of the business case drivers is on four different central pillars of a business model: the value proposition, customer relationships, business infrastructure and financial aspects. This implies the need for changes to the company's business model (i.e. business model innovation) which may range from incremental to radical adjustments. Business model adjustment is about changing only one or a few business model pillars (i.e. not the value proposition). Business model adoption means adopting the company's business model to match competitor's efforts. Improvement refers to improvements in a majority of business model pillars while leaving the value proposition unchanged. Finally, for business model redesign also the value proposition is adapted. The first two can be related to a more defensive strategy, business model improvement can be linked to an accommodative strategy and finally proactive strategies lead to business model redesign. Thus, in order to create a business case for sustainability, business case drivers need to be addressed and this requires business model innovation leading to a certain degree of business model adaption. However, adapting a business model is by no means an easy task at all. Managers tend to remain doing business as usual as they base their actions on what they already know (i.e. available information flows) and been successful with and what will lead to a high personal reward (Chesbrough, 2010). It is also not always known what the right model should be. However, experimentation and organizational adaptation can be of help in overcoming these issues and creating new business models (Chesbrough, 2010; McGrath, 2010).

2.3 A combined perspective for analysis

The impact of PV CSV business cases will be analyzed from both an individual firm and a transition studies perspective. At individual firm level it will be assessed what the main drivers for performing the project were and how this relates to the sustainability strategy of the company. The PV CSV business model as well as linkages with the company's core business model will be mapped. Also, it will be analyzed to what field of CSV the project can be attributed (i.e. Reconceiving products and markets, Value chain, Cluster building). The contribution to social and environmental change (i.e. scaling up of the Dutch PV market) will be evaluated using Strategic Niche Management (SNM). The contribution of the different PV CSV business model experiments will be evaluated by conceptualizing them as labs, windows or agents of change respectively. Using SNM this will be put into context by revealing existing regime barriers and broader niche developments.

3. Methodology

Based on an initial desk study including various literature sources like sector reports, websites, newspaper articles, conference presentations and our earlier study of Dutch PV market developments I created a first overview of the various types of CSV PV business models operating in the market. For each of the found business models I will select one company for doing a semi-structured interview. As CSV is not only about value that is being created for the core company, but also for other actors, I will also interview these (i.e. only those directly involved, first circle of actors surrounding the company). Interviewees will be asked for their permission for using the information provided in the interview. Also, they have the opportunity to check interview transcripts before further processing. The interview starts with general questions about the company and its sustainability strategy. Next the CSV business model will be mapped using the mapping methodology of Osterwalder and Pigneur (2010) who define a business model as consisting of nine building blocks: customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships and cost structure (Osterwalder and Pigneur, 2010). Also, the degree of adaptation of the core business as well as business case drivers will be questioned. This will be followed by a section on the broader contribution to the Dutch PV market (i.e. project as lab, window or agent of change). Also, I will ask interviewees about their expectations of the potential of CSV projects in the future and more generally on the development of the Dutch PV market. Finally, I will ask for things they missed in the interview as well as other actors within and outside the project (other CSV projects) to be interviewed (i.e. snowballing). Actors other than the core company will be interviewed using an adapted list of questions.

4. Results

Below I will discuss initial findings which are based on the performed desk study. Two main categories of business models were found. In the first a PV system is mounted on the roof of the company, potentially with external funding. For the other category the core company is actively involved in making PV systems available for other market segments. Below I will shortly discuss each of the found business models. A summary of the found business models and their main properties (e.g. degree of business model adaptation, drivers) can be found in *Table 1*. It should be noted that for some of these business models multiple projects are executed while for others only a single project was found. Next, contributions to broader scaling up of the Dutch PV market will be discussed.

4.1 CSV Business models

4.1.1 PV system on own roof

Investment on own roof

A number of SMEs in the Netherlands have invested in PV systems on their own roof. In the Netherlands, households and SMEs pay the highest price per kWh because of high energy taxes and therefore PV is an interesting alternative. Large companies pay less energy taxes and therefore PV is not competitive for them. However, recently a few large companies have invested PV systems on their roofs. For example, in March 2013 Heineken has installed about 3600 panels on their brewery in Den Bosch (Solar Magazine, 2013). This was accompanied by an advertisement on the Dutch national television. Reputation and brand value have been important drivers for this project as the business case itself is negative. Additionally it is possible for a group of companies to form a cluster and collectively buy PV systems thereby arranging a discount. For example, fifty agrarians joined forces and together installed 1,2 MW (Atama, 2013). The agrarian branch organization LTO assisted in the management of the project thereby reducing technological and investment risks for the farmers. The above mentioned projects do not lead to significant changes in the business model of the core company (i.e. business model adjustment). Furthermore, 28 farmers are currently involved in the 'Boerzoektbuur' (Farmer searches Neighbor) project (Boerzoektbuur, 2013a). Neighbors can buy coupons for organic food produced by the farmer which they have to spend over the next six years. Part of the revenues is invested in a PV system on the roof of the farmer's barn. This means a new value proposition to customers who previously could buy products whenever they liked and therefore a relatively high degree of business model innovation (i.e. business model redesign). Again a third party was included for assisting in the management of the business model. From a CSV typology the above described business models can be considered as value chain CSV opportunities (i.e. energy use and logistics).

External investment

Additionally, there are companies offering lease contracts to SMEs. However, there are limitations to the type of SMEs that can join such projects. For example, Rooftop Energy only provides systems to small scale users (maximum 3*80 Ampere connection) with a minimum use of 8000 kWh (Rooftop Energy, 2013). Again, this business model can be considered as a value chain CSV activity.

4.1.2 Contributing to business models for other customer segments

Investment on external roof

In February 2012 a freelancer financed a PV system on the roof of friends (Boerzoektbuur, 2013b). The project was initiated and managed by the Centre for Inclusive Science (i.e. also involved in the Farmer Searches Neighbor project). The business case is profitable, because the freelancer can make use of tax deductions and the household is benefitting from net metering regulations[1]. The business model has also been applied to other company-neighbor couples. For example a company has invested in a PV system on the roof of the local scouting association (Anne Strijkel, 2013). Additionally, a combination between the Company Searches Neighbor and Farmer Searches neighbor business models has been developed. In Amsterdam, customers can buy coupons at the local Ecoplaza supermarket (organic supermarket) (Purpura, 2013). Part of the revenues is used for investment in a PV system at a nearby school building. Thus, similar to Farmer Searches Neighbour a new product is offered to the customers (i.e. reconceiving products and markets).

PV for employees

A number of PV system suppliers and installers in the Netherlands are offering companies the possibility to provide their employees with PV systems. By collectively buying PV systems employees receive a discount. Also, they do not have to take care of selection of a supplier themselves. The Dutch telecom provider KPN has signed an agreement with the Dutch PV system supplier (and installer) Oskomera to provide their employees with PV panels (Oskomera, 2013). By doing so, KPN aims at involving their employees in making their company more sustainable. Also, they will stimulate their own suppliers to invest in PV systems. Another option is to finance the PV systems of the employees and to reimburse the investment via their salary. In April 2012, the municipality of Leeuwarden was the first to do this (Gemeente Leeuwarden, 2013). Based on their experience they have created a booklet for other organizations on how to organize such a project.

Contribution to an experiment for expanding of existing legislation

In the Netherlands it is not allowed by the national government to apply net metering in case a PV system is not located on your own roof (i.e. so called virtual net metering). However, there are a few experimental projects in which virtual net metering is applied. In one of these, citizens can buy a share in a PV system on the roof of a nearby activity centre (4 New Energy, 2013). The advantage of this business model is that citizens who do not have a suitable roof or large amount of money available can still invest in PV. Virtual net metering is applied by the Dutch Distribution Network Operator

[1] Net metering is the deduction of kWh delivered back to the grid from kWh taken up from the grid. Customers only have to pay for the net amount of electricity used.

(DNO) Alliander. The local municipality guarantees for two years of compensation in case the national government decides to collect the taxes they normally apply in such a case.

Business Model	Core Company	Partners	Core Company role	Type of CSV	BM adaptation	Drivers
SYSTEM ON OWN ROOF						
Company invests in system on own roof:						
- Individual	SME, Large company	Supplier/Installer	Making investment	Value Chain	Adjustment	Costs, Reputation
- Collective	Farmer	LTO	Making Investment	Value Chain	Adjustment	Costs, Reputation
Investing part of product revenues in PV	Farmer	Institute for Inclusive Science	Making investment, offering new value proposition to customers	Value Chain, Reconceiving Products and Markets	Redesign	Costs, Reputation, Sales
Third Party investment	SME	Rooftop Energy	Making Roof available	Value Chain	Adjustment	Costs, Reputation
CREATING BUSINESS MODEL FOR OTHER CUSTOMER SEGMENT						
Investment on external roof	Freelancer	Institute for Inclusive Science	Financing panels on different location, arranging contract	N.A.	Adjustment	Reputation
→ coupled with product sales	SME	Institute for Inclusive Science	Financing panels on different location using product sales revenues, arranging contracts, offering new value proposition to customers	Reconceiving Products and Markets	Redesign	Reputation, Sales
PV for employees	Large company, SME	e.g. Centrosolar, Oskomera	Investment in organization of project, financing (optional)	N.A.	Adjustment	Reputation, Attractiveness as employer
Community Shares	SME	4NewEnergy, Municipality, Alliander	Making roof available for experiment	N.A.	Adjustment	Reputation

Table 1: CSV business models found in the Netherlands (2008-present).

4.2 Contribution to scaling up of the Dutch market

As stated above projects like those described in S*ection 4.1* can contribute to scaling up of the PV market by acting as a lab, window or agent of change respectively. The projects organized by the Institute for Inclusive Science are an exception. A lot of information on how these were developed can be found online. For all companies doing a PV project it meant cooperating with new actors. New, small networks were formed to organize and operate the various projects. Interestingly, in almost all cases an external party was involved in managing the project for the company. However, learning between projects or global niche formation seems to be limited. Possibly this is happening via the external parties that are assisting the core company with setting up a PV CSV business model. Also, one of the projects (Community Shares) was found to aim at working as an agent of change by contributing to the discussion on and possible extension of the legislation for virtual net metering in the Netherlands. Additionally, various CSV business models are including previously excluded market segments thereby directly contributing to PV market growth. These include people who cannot manage buying a PV system themselves or those who cannot make the initial investment or do not have a suitable roof available. Also, one of the companies is stimulating PV projects at their own suppliers. Spillover effects in the own company (i.e. new PV or sustainability projects), to related project stakeholders or to other companies are interesting topics for further research (interviews).

5. Discussion and Conclusion

In recent years a number of SMEs and large companies in the Netherlands started a PV project. These were previously unrelated to the PV or energy market in general. Based on initial findings I have tried to analyze what these projects meant for the individual company as well as for PV market growth in the Netherlands. By so doing, I aim to contribute to a better understanding of the concept of Creating Shared Value (CSV), in particular on how company’s applying CSV business models can contribute to wider niche development processes. Two main CSV business model categories were found: PV systems installed on the roof of the company and PV systems installed on roofs of external parties resulting in different roles for the core company involved. The first was mainly driven by cost reduction and reputation drivers and included little business model innovation for the core company. Interestingly, also large companies have invested in PV systems on their roof even though the business case itself is unprofitable. An exception was found in the combination of product sales with investments in a PV system on the company’s roof (i.e high level of business model innovation; sales as direct driver). For the second category, reputation seems to play an important role as the company is involved in the organization and financing of PV systems for external parties like neighbors or employees. Again relatively little business model innovation took place except for the business model in which the core company was using product revenues for investment in a PV system on an external location. This raises the question to what extent these projects can be considered as CSV projects or whether they are more in line with traditional CSR activities which are unrelated to the core business of the company or whether they should even be considered as green washing activities. However, further research is needed to investigate if PV projects have resulted in new sustainability projects in the company (or in related stakeholders' organizations) and if further business model innovation in the direction of a fully social business model is happening. Also, even though the linkage to the core business of the company and degree of business model innovation may be weak, value creation for the core company and other stakeholders can be high (e.g. in terms of cost savings). Another interesting point is the fact that for all projects an external party is involved in management and organization. Little networks of PV system suppliers and installers, the core company and an external management organization are formed. This confirms the importance of partnerships for CSV. It also means that value is not only created by activities of the core company. This raises questions about what type of value is created, by whom it is created and therefore on how to assign value to the core company (i.e. for CSV measurement procedures, see Porter et al., 2012). Also, the concept of CSV raises questions on the types of companies that can be assigned a CSV label. Are all PV suppliers and installers by definition creating shared value because their main business is to provide society with clean energy? And how does the concept relate to social enterprises which by definition work from a CSV perspective? Also, the three types of CSV as defined by Porter and Kramer (2011) were problematic in the sense that a few projects could neither be categorized as a CSV Value chain, Reconceiving products and markets or a Cluster building activity.

Finally, various contributions to the scaling up of the Dutch PV market were found. A number of CSV business models are aiming at including previously excluded market segments (e.g. those without a suitable roof or financial resources). All projects can be considered as windows as in all cases new actor coalitions were formed around the project. Global niche formation seems to be limited, but more research on this topic is needed. Also, more research is needed on spillover effects of the investigated PV projects. Finally, one of the projects aims at working as an agent of change by provoking discussion on the extension of the national legislation for net metering that is currently in place. However, these activities are only part of a broader array of niche development activities and niche-regime interactions that are ongoing (see Huijben and Verbong, 2013). Though the overall outcome of such processes remains to be seen, it is clear that companies are not just creating value for society by their PV projects, but are part of a more structural process that is ongoing: the Dutch sunrise.

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Harbour bathing and the urban transition of water in Copenhagen: mediators, junctions and embedded urban navigation

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Abstract

In 2002 the first harbour bath in the inner harbour of Copenhagen was opened. Harbour bathing has since evolved into an institutionalised urban practice that provides direction and momentum to transitions in the wastewater sector and to the role of water in city. This study explores how the first bathing facility in the harbour came about and initiated this development. Empirical data were gathered and validated by the alternation of two sources: historical documents produced by relevant institutions and organizations and by face-to-face semi-structured interviews with actors directly and indirectly involved in the harbour transformation in Copenhagen. The study informs a novel understanding of transition processes in urban contexts that introduces the notions of junctions, embedded urban navigation and transition mediators. These concepts suggest urban contexts are characterised by an on-going generation of tensions and contradiction among practices and subsystems. Urban transition processes are conceptualised as the outcome of embedded actor's navigation in response to these contradictions and tensions. We employ this understanding of urban transition processes to inform our analysis of the emergence of harbour bathing as a transformative urban practice in Copenhagen. The concepts of junctions, embedded urban navigation and transition mediators help to identify and appreciate how embedded strategic micro politics within urban contexts displace the boundaries and logics of urban sub-systems.

Introduction

In 2002 the environmental mayor of Copenhagen jumped into the water of the inner harbour basin of Copenhagen. She thereby declared the first public harbour bath in modern times in the inner harbour of Copenhagen open. The bath quickly grew into a great success and several more bathing facilities have opened in the harbour since.

In this analysis we conceptualise these harbour baths as urban transition mediators. An urban transition mediator is a project or intervention which orchestrates path creating change by cultivating cross-cutting associations among hitherto compartmentalised urban practices and infrastructures. Transition mediators thereby displace the traditional boundaries and logics of urban sub-systems.

The harbour bathing qualifies as such a transition mediator for two reasons. First, harbour bathing has evolved from an experimental to an institutionalised urban practice. Today the citizens of Copenhagen expect to be able to bath in the harbour and harbour bathing is perceived as a trademark of the green city. This implies that the harbour baths are unlikely to close down, even if conflicts should develop in relation to other concerns or priorities of the city. Secondly the practice of harbour bathing constitutes a key node in a new configuration of socio-material interdependencies within the urban context of Copenhagen. These new interdependencies are related to the urban wastewater infrastructure because the harbour basins, in which the bathing facilities are located, are connected to this infrastructure. In addition to provide hygienic drinking water, the urban wastewater infrastructure now also provides hygienic bathing water in the harbour. The harbour baths are also associated with the discourse of the green liveable city and harbour bathing have been extensively exploited in the international marketing of Copenhagen.

By institutionalizing new cross-cutting associations among urban practices and infrastructures, the harbour baths have played a significant role in establishing a set of new path creating urban agendas. One of these agendas concerns the relation between the urban wastewater infrastructure and the broader urban context. Rather than providing drinking water through an infrastructure which is invisible to the public (underground pipes and sewers and publicly ignored wastewater recipients) the strategy now is to make this infrastructure increasingly visible in order to use water to generate urban value. Urban planners and architects also perceive recreational practices, located at the harbour front or in the water of the harbour itself, as an increasingly central element of the urban experience of Copenhagen. The harbour and the water in the city have accordingly become the new hot spots of urban development.

In this paper we analyse how harbour bathing came into being as a transition mediator. In doing this the paper explores the navigational transition dynamics within the urban context of Copenhagen. We employ the notion of navigation because the harbour baths were not established as the outcome of long-sighted and deliberate strategic transition governance processes, or as a preconceived endpoint of a strategically envisioned transition pathway (Roorda et al. 2012). They were rather established through the myopic manoeuvring of actors embedded in the urban context.

The paper is divided into two parts. The first part offers a case description of how the first harbour bath came into being and introduced harbour bathing as a new urban practice. The second part develops the concept of embedded urban navigation, and analyses the case as an example of such navigation.

The enactment of a transition mediator

This section demonstrates how the opening of the first public harbour bath in the inner harbour of Copenhagen was preconditioned by 20 years of navigation by different urban actors. This navigation embedded the harbour in different urban configurations. Below we analyse the development of these configurations and their relation the opening of the first harbour bath in 2002. The empirical data in the study consists of municipal planning documents and semi structured interviews with actors directly and indirectly involved in the harbour transformation in Copenhagen.

Configuration 0: Point of Departure

Since the 1920s the primary urban function of the inner harbour basins in Copenhagen was to provide infrastructure for the industrial activities of the city. The harbour served both as a transport corridor to ships providing goods and raw materials to the industries of the city and also as recipient of industrial wastewater from the manufacturing activities. In the 1950s it was officially forbidden to bath in the harbour and in most coastal areas in near proximity of the city for reasons of public health.

Since the 1960s the inner harbour did not under normal circumstances function as a main recipient for the city’s sewer system. Rather the sewage water was pumped into the open water of Øresund through long pipes. In the early 1980s, a modern wastewater treatment plant was opened in order to mechanically and biologically process the sewage water before it was pumped into Øresund. The harbour was, however, still a key component of the urban sewage system because the capacity of the sewer system and the waste water treatment plant was frequently exceeded in case of rain. In order to avoid overflows of sewage water in the city itself, excess water was directed into the harbour basins. The industrial contamination and traffic in the harbour as well as the overflows from the sewage infrastructure was more or less taken for granted, since the harbour served a series of functions and needs pertaining to fundamental urban activities and infrastructures. This was a relatively stable urban configuration that consisted of an aging wastewater infrastructure, which had been developed to avoid too much obnoxious smell in the city. In relation to this infrastructure the harbour functioned as recipient of overflows of sewage water in case of heavy rain. These overflows were experienced as relatively unproblematic because the harbour was already contaminated by industrial activities.

Configuration 1: The Environmental Preservation logic

Despite the harbour’s embeddedness in a relatively stable urban configuration the inner basins of the harbour nevertheless became a key node in a series of processes, which transformed the harbour from a contaminated industrial area and into a symbol of the green liveable city.

These processes were initiated in response to a series of challenges facing the development of the urban sewage infrastructure, which began to build up from the early 1980s. One challenge was related to a general maintenance deficit of the sewage infrastructure. During the 1980s it became increasingly evident that some of the oldest clay sewers needed repair or replacement and there was furthermore increasing problems with rats. Still, maintenance activities were not reactive. Problems were only acknowledged and resolved once they were reported and there was little systematic maintenance aiming to prevent problems in developing further. Also, there were no overall plans for how to develop the infrastructure in its totality. The planning and maintenance practices hence divided the system into a series of local catchment areas, and no strategies for how to cope with the interdependencies among these catchment areas were developed. Also the planning activities did not question the overall design criteria, which was to avoid too much obnoxious smell from the sewage system.

Environmental awareness started to grow, becoming visible through social movements, and anchored in a new Ministry of the Environment. However, it had already begun penetrating policy formulation and regulations from the 1970s. On the base of this, concerns regarding the sewage systems biological impacts on the water recipients of the city started to emerge. More specifically, this environmental perspective was promoted within the municipal administration by a new strategic planning instrument called ‘wastewater plans’ that were introduced in the late 1970s. During the 1980s a more systematic monitoring of the biological conditions of the urban water recipients connected to the wastewater infrastructure was introduced based on these plans. In the urban context of Copenhagen, this information was initially not translated into new design or performance criteria for the wastewater infrastructure during the early1980s. The environmental perspective did hence have little direct impact on actual maintenance and system design. Stronger political attention towards the biological condition of water recipients however developed in 1987, when many Danish coastal waters suffered from oxygen depletion due to heavy emission of nutrients. Media images of dead fish and lobsters sparked public debate. The national political response was the first Action Plan for the Aquatic Environment, which aimed to reduce phosphor emissions by 80% and nitrogen emissions by 50% in five years. The direct outcome of this was a construction boom in wastewater treatment plants that could take away nutrients from urban waste water.

In Copenhagen, the maintenance and development of the wastewater infrastructure was the responsibility of a municipal department called the sewage office. Within this office the tensions between the traditional inactive and largely uncoordinated planning and maintenance practices and the growing political attention on environmental quality became increasingly present. However, the situation remained strategically opaque because no clear political priorities had been set for the development of the infrastructure itself. Despite the lack of priorities, there was nevertheless an increasing political pressure to increase spending and deliver improvements. The situation culminated in an open conflict within the sewage office in the early 1990s. On the one hand, the planning director, who formally headed the office, felt that the political priorities were too weak to engage in any overall strategic planning and opted for no action. On the other hand, a water engineer, working in the same office, believed that a more active planning role was needed, despite the lack of clear political priorities. He had also noticed how revenues from wastewater taxes had been building up, and how these revenues were being channelled into the development and maintenance of other infrastructures. He acted by writing a letter to the city engineer, where he explained the situation as he saw it, and persuaded his younger colleagues to sign it. To solve the situation, the planning director retained his position, while his staff was reorganized into a new independent planning section where they could play the more active role they had argued for.

At the same time the environmental data concerning the state of the water recipients began to be translated into political priorities for the wastewater infrastructure. During the 1980s, environmental protection had hence developed into an institutionalised area of regulation within the municipal administration. In 1993, the municipal office for environmental monitoring issued the first comprehensive plan with a clear environmental perspective for the wastewater infrastructure. This plan provided a coherent overview of the environmental condition of the urban water recipients. The environmental quality of the recipients was measured on two parameters: The biological quality and the chemical/toxicological quality. The chemical/toxicological quality focused on the sediments in the inner harbour, which were highly contaminated by heavy metals from the industrial manufacturing in the harbour. The biological quality was related to the levels of nutrients, to the visibility in the water, and to the biological diversity of fish, plants and microorganisms. Based on this analysis an environmental goal for the inner harbour was decided. This goal was defined in relation to the biological 'basic state' of the recipient, which referred to the natural state of the recipient in the absence of human any influence. For the inner harbour, the goal was defined as 'general quality' meaning no or weak human influence on the life of plants and animals and good hygienic conditions. 'General quality' did however not include specific requirements for e.g. bathing conditions or biodiversity protection. This environmental goal was translated into two strategies for the inner harbour. The primary strategy was a reduction of overflows from the wastewater infrastructure to the harbour in the case of rain and the second strategy was to clean up the contaminated sediments. Based on this plan a target to reduce the overflows by 50 pct. was set in a wastewater plan two years later.

These more strategic wastewater plans provided a new and stronger political mandate for the newly established planning section. For the section leader an opportunity to test this mandate arose in 1996, as he was contacted by a manager of the harbour who offered a two years window-of-opportunity for establishing a large underground water retention facility in the harbour basin at Nordhavn (North Harbour), which was to be closed down and landfilled. The manager of North Harbour was interested in such a facility mainly because it would reduce the sedimentation of the channel that ensured access for larger vessels. For the leader of the planning section this retention facility offered an opportunity to significantly increase the overall retention capacity of the wastewater infrastructure and hence reduce the overflows to recipients in case of heavy rain. Later that year, the municipality endorsed the investment, which did not result in increased tariffs due to the existing accumulated revenue. For the new planning section this investment marked a significant breakthrough, since it represented the largest strategic investment in the infrastructure for decades. The endorsement of this water retention facility was soon following by the endorsement of the construction of another large water retention facility in Sydhavn (South Harbour). The opportunity for this facility emerged as a power plant shifted its fuel from coal to gas, whereby the coal storage areas became available for the establishment of a new water retention facility.

Alongside the technical improvements of the wastewater infrastructure, a vision on the possibility of using the harbour for recreational activities started to emerge. These visions however remained rather unspecific. One idea was to use the harbour for fishing. A sport fisherman was e.g. used as illustration on the front page of the 1993 water recipient plan. Another idea was to use the harbour for sailing and canoeing. In the second part of the 1990s more specific visions for how to realise the recreational potentials of the water in the city began to appear. These visions were for the most part influenced by a nature perspective suggesting that the water in the city should be used to provide experiences of nature as an alternative to urban life. One vision was to re-create the inner lakes of Copenhagen as a natural environment by cleaning up the lakes and transform them into a habitat for fish and birds. A part of this vision was to create a more nature-like aesthetics expression by replacing the concrete constructions along the shores of the lakes with wood constructions. Also the nature perspective was central to visions for the inner harbour. One such vision was called the 'harbour aquarium'. The idea was to construct an underwater tunnel of glass where the public could enter into harbour and experience the aquatic life. An element of this vision was to construct an artificial reef in the harbour, in order to attract more aquatic species. The funding for realising this project was however never granted.

As demonstrated above the harbour became an element of a new urban configuration informed by an environmental preservation logic during the 1980s and early 1990s. Within this configuration the urban water recipients of Copenhagen were subjected to biological water quality standards, which functioned as stepping-stones for the formulation of a coherent strategy for the development of the urban wastewater infrastructure.

Configuration 2: The hygienic-recreational logic

The urban configuration informed by the nature preservation logic was however soon complemented and partly challenged by the emergence of yet another urban configuration informed by a hygienic-recreational logic. While the environmental preservation perspective that had been building up throughout the 1980s became central in the plans for the wastewater infrastructure from the early 1990s, also a new recreational perspective hence emerged in this period. This perspective was related to the de-industrialization of the harbour. By the late 1980s much of the traditional industrial activity had moved out of the harbour, and the harbour was gradually turned into an abandoned industrial area. As a response the municipality formulated a long-sighted strategy to transform the harbour into a commercial and residential area. To support this area transformation the harbour was envisioned as a potential site of recreational activities. The water recipient plan from 1993 hence stated that the harbour should have a water quality 'suited for recreational purposes'. In this plan the recreational perspective however remained peripheral and partly detached from the dominating environmental preservation perspective. It also remained unclear what the recreational practices in the harbour would actually be, and what these practices would imply for the water quality of the inner harbour. Though the specific implications of the recreational visions remained unclear, this perspective was nevertheless given a more central position in the wastewater plan, which followed two years later. Here it was stated that investments in the wastewater infrastructure should support the use of the inner harbour for recreational activities.

Specifically this entailed that investments in the wastewater infrastructure connected to the inner harbour had to be prioritised, at the expense of investments in the infrastructure related the North Harbour, although these investments would have a bigger environmental preservation impact.

Within the new planning section the vision to use the harbour for recreational purposes was translated into an alternative strategic priority for the development of the wastewater system. This new priority emerged because recreational activities, such as e.g. canoeing and wind surfing, implied that humans would come into direct contact with the water in the harbour. In order to ensure the human safety of such recreational activities, the planning section believed that hygienic water quality parameters needed to become a more central priority for the design of the wastewater infrastructure. In contrast to the biological water quality parameter, which primarily focused on the level of nutrients in the water, the hygienic water quality parameter focused on the level of pathogenic bacteria in the water. The EU standard used the level of E-coli bacteria as proxy for the level of pathogenic bacteria and stipulated that the level of E-coli bacteria should be below 1000/pr. mg, 95 pct. at the time of the bathing seasons.

In the early 1990s, the idea to employ the hygienic water quality standard as design criteria for the wastewater infrastructure however remained an internal discussion within the planning section. The planning section's focus on hygienic water was however strengthened during the 1990s. This was partly related to the experience of considerable political support and room for manoeuvre in relation the endorsement of the first large water retention facility in the North Harbour in 1996. The decision process hence demonstrated to the planning section that investments in the infrastructure did not need to be narrowly related to the political goal of reducing the overflows by 50 pct. Rather than planning narrowly for a 50 pct. reduction, the planning section had chosen to opt for the largest possible design of the facility, and it was this solution which was endorsed. The planning section's focus on the hygienic water quality parameter was also encouraged by measurements of the level of E-coli bacteria in the inner harbour, which had been initiated by an employee in the office of environmental monitoring. The data showed that that water in the harbour generally complied with the bathing water standards. The level of E-coli only exceeded the standards in the case of overflows caused by heavy rain.

The planning section's focus on promoting compliance with the hygienic water standard became increasingly strategic in relation to the planning of the second large water retention facility. This facility was also more critical to the water quality of the inner harbour because it was located to the south of the harbour, which is where the stream in the inner harbour often comes from. The politically decided water quality goal for the inner harbour was however still based on the biological water quality standard, and stipulated a 50 pct. reduction of overflows to the harbour as the goal. This reduction would not be sufficient to ensure hygienic bathing water quality. Informed by their internal hygiene agenda the planning section however now more deliberately operated on the fringes of their political mandate as defined in the wastewater plans. They anticipated that the hygiene agenda could potentially become a target for external critique, because the investments would ultimately be financed through wastewater tariffs that heavily burdened large breweries located in the city. A strong pressure could be expected if these companies realised that their tax money was used for ensuring hygienic water, which was a design criteria that had no official political mandate. The planning section accordingly designed a less ambitious facility than they preferred. Still, the hygienic water quality standard was deliberately introduced in the proposal endorsed by the municipality. Now bathing was for the first time mentioned as a potential recreational activity. Also, the proposal included funding to develop a computer-based model to describe the hygienic impact of overflows from the wastewater infrastructure. The purpose of this model was to provide the planning information needed for further investments aiming to ensure hygienic bathing water quality.

The endorsement of the proposal indicated a more political shift towards the recreational agenda with focus on the hygienic water quality of the harbour. This shift was symbolically reflected at the opening of the water retention facility in the South Harbour. At this event, the environmental mayor illustrated the implications of the new water retention facility by canoeing in the water of the harbour. The two large water retention facilities and the lobby work of the planning section together developed the path for the introduction of hygienic bathing water as a new design criteria of the wastewater infrastructure connected to the inner harbour in a new wastewater plan in 2000.

In the late 1990s the conception of recreational activities was still framed within a nature perspective as illustrated by the vision of ‘the harbour aquarium’. Few years after the turn of the millennium the first bathing facility was nevertheless opened in the inner harbour of Copenhagen. Compared to the nature preservation perspective that dominated in the late 1990s, harbour bathing represented a very different conception of recreational activities. Rather than using the water of the city to provide nature experiences as an alternative to urban life in the city, bathing now constituted an integrated urban practice where the harbour had become city-nature. As a recreational practice bathing did hence not offer an experience of a biological habitat. Bathing rather integrated the water in a new “green” form of urban living.

The specific events that led to the opening of the first harbour bath unfolded within a short period of only half a year. These events were initiated as Copenhagen somewhat provocatively proclaimed itself the environmental capital of Europe. The mayor of Stockholm however criticised that statement on the base that bathing was not permitted in the harbour of Copenhagen, which was not the case in the waters surrounding Gamla Stan in Stockholm. At the same time a harbour festival was arranged at the shores of the inner harbour of Copenhagen. In relation to this event a local diving association called ‘The big splash’ applied for permission to use the harbour basins for a series of diving shows. Due to the improvements in the wastewater infrastructure, the diving association got the permission on the condition that the water was not contaminated by overflows from the wastewater infrastructure during the event. During the festival an employee from the municipal office of environmental monitoring regularly visited the festival to assess by sight if any problematic overflows were compromising safety. The diving shows in the harbour attracted great public interest. This inspired the president of the diving association to organise a signature campaign to promote a permanent diving and bathing facility in the harbour basin. With these signatures in hand the president approached the environmental mayor, who was already interested due to his dialogues with the mayor of Stockholm. The environmental mayor succeeded to promote the project, because his party was part of the municipal budget negotiations that year. In these negotiations the environmental mayor promoted the harbour bath as a symbol of his party's green profile. The first harbour bath facility hence became part of the municipal budget in 2002. This budget agreement also included funding for a computer based monitoring system that could simulate how the hygienic water quality in the harbour was affected by overflows from the wastewater infrastructure. Later that year the first harbour bath opened.

As illustrated above the environmental preservation logic, which developed in the early 1990s, was complemented and partly challenged by a new urban configuration informed by a hygienic-recreational logic during the late 1990s. An element of this configuration was the conception of the harbour as a site of recreational activities. In the late 1990s this conception of the harbour was associated with hygienic - rather than biologic - design criteria for the wastewater infrastructure. Based on this hygienic design criterion the first harbour bath opened in 2002. Rather than providing an experience of a biological habitat, harbour bathing is a recreational practice that associated the harbour with a new "green" form of urban living.

Urban configurational shift: junctions, embedded urban navigation and transition mediators

In this section we develop a generalized conceptual interpretation of the urban transition processes illustrated by the harbour bath case. The case illustrates that the first harbour bath in Copenhagen was the outcome of embedded navigation by a series of actors within the urban context of Copenhagen. We conceptualise such embedded urban navigation as myopic strategic work that unfolds in the context of junctions within the urban context.

Junctions

We introduce the concept of junctions to highlight the distinct transformative dynamics of complex, multi-functional sites such as an urban context. A salient characteristic of such sites is that they are made up of many different practices and subsystems by which societal functions such as transport, leisure, water, housing and food is provided and used. Taken individually such practice and sub-systems are often characterised by interdependencies and reciprocities that leads to strong path dependencies and lock-ins (Geels, 2002). In a multifunctional urban context it however makes limited sense to understand practices and subsystems individually as these seldom operate independent of one another. Also the generation of urban order among practices and sub-systems is myopic and distributed. While overall urban plans and strategies may exist, such plans and strategies are for most part also characterised by compartmentalised perspectives and objectives. Thus, their capacity to efficiently integrate and control the processes, by which urban order is concretely produced through the daily practices and enactments of urban infrastructures, is limited. Urban contexts may hence be addressed as a series of interdependent but weakly integrated orders generated by a series of situated socio-material assembly processes (Farias and Bender, 2010). This entails that the practices and sub-systems of urban contexts interpenetrate each other in complex ways that make up a dynamic pattern of tensions, contradictions and ambiguities. We introduce the notion of junction to refer to these tensions, contradictions and ambiguities within and among urban practices and subsystems. The notion of junction thus highlights how urban practices and sub-system exist in a dynamic series of tensions and interdependencies with one another.

The case above illustrates the importance of junctions in urban transition processes. The shift to the environmental preservation logic was hence conditioned by the transformation of the urban water recipients into an urban junction in the 1980s. Until the early 1980s these recipients had been more or less ignored by the public. This was partly due to the design of the urban wastewater infrastructure itself, which prevented the development of obnoxious smells that could raise public concern. In the late 1970s environmental protection however emerged as a new area of regulation within the municipal administration. One of the elements that constituted this new area of regulation was wastewater plans, which defined the urban water recipients as biological habitats. This translated the urban water recipients into a junction, i.e. ambiguous element of the urban context which was conceived both as recipient of wastewater by the municipal sewage office and as a series of biological habitats by the municipal office of environmental protection.

Another urban junction conditioned the shift to the hygienic-recreational logic. This junction was related to the de-industrialisation of the inner harbour with became increasingly evident in the late 1980s. In light of this process the municipality formulated a strategy to transform of the inner harbour from industrial to commercial and residential area use. This established the harbour itself as an urban junction. Rather than a biological habitat, the harbour was accordingly conceived of as a site for recreational activities. Again the harbour was translated into a junction as its existing urban identity was questioned by the vision of the harbour as site for recreation.

Embedded urban navigation

The emergence of junctions entails that urban contexts are characterised by embedded socio-technical ‘repair work’ aiming to continuously re-contextualise existing practices and sub-systems within the dynamic conflict-ridden urban context. We introduce the notion of embedded urban navigation to signify the combined strategic work of re-contextualizing and re-configuring practices and subsystem within a dynamic and conflict-ridden urban context. More specifically we argue that embedded urban navigation is related to junctions that provoke the socio-technical configurations of existing urban subsystems. Since junctions signify contradictions and tensions among urban practices and sub systems, embedded urban navigation often entails the generation of new associations and interdependencies across traditional system boundaries. Such navigation may hence displace traditional system boundaries and enact new system logics. The notion of embedded urban navigation further suggests that the on-going re-contextualization and reconfiguration of urban practices and subsystem do not follow a single and predictable causality. These processes are rather constructed by the active situated interpretations, alliances and interventions of embedded actors.

The case above illustrates different types of urban navigation. The embedded urban navigation related to the water recipient junction was primarily concerned with developing the capacity to strategically plan and implement solutions. During the early 1980s the junction hence remained too weak to successfully provoke the existing urban configuration, in which the urban water recipients were embedded. The municipal sewage office thus initially succeeded to marginalise the new biological conception of the urban water recipients in their actual planning of the maintenance and development of the wastewater infrastructure. The junction however grew stronger as a more robust and coherent biological conception of the urban water recipients was building up towards the end of the 1980s as a consequence of the first National Action Plan of the Aquatic Environment. This conception finally translated into different lines of embedded urban navigation in early 1990s. In the municipal sewage office the more coherent and robust biological conception of the recipients provided a lever for an explicit critique of the hitherto reactive and uncoordinated planning practices related to the maintenance and development of the wastewater infrastructure. This resulted in the establishment of a more strategically active planning section. Independent of these processes the municipal office of environmental monitoring succeeded to translate the data concerning the biological conditions of the urban water recipients into strategic design criteria for the wastewater infrastructure. These design criteria enabled the new planning section to exploit opportunities for constructing two large water retention facilities in the late 1990s. Finally, a vision to use the harbour as a site for public experiences of an aquatic habitat was developed in the late 1990s. This recreational vision was however not realised.

The embedded urban navigation related to the recreational harbour junction was less about building strategic capacity to plan and act. This embedded navigation was rather an example of strategic manoeuvring aiming to change the dominant environmental preservation logic. By the newly established planning section the recreational harbour junction was hence further translated into a focus on hygienic design criteria for the development of the wastewater infrastructure. In the early 1990s the hygienic water quality focus only existed internally in the planning section. In the second half of the the 1990s the section however succeeded to strategically promote the hygienic water quality standard as a new design criteria for the wastewater infrastructure. Two strategies were used. One strategy was to upscale the two new water retention facilities beyond the specific goal of a 50 pct. reduction in overflows. This strategy was however balanced in order to avoid potential conflicts with the industry over the water tariff financed investment in the infrastructure. The other strategy was to promote the hygienic water quality standards in the decision documents endorsed by the municipality. By combining these two strategies the planning section succeeded to introduce the hygienic water quality standard as an official design criterion for the wastewater infrastructure related to the inner harbour in 2000. As the hygienic water quality standards gained foothold during the late 1990s, the conception of recreational activities related to the water in the city was still formulated within an environmental preservation perspective. Due to urban navigation that unfolded independent of the sphere of water professionals a different conception of recreational activities however emerged in 2001. During a harbour festival, a diving association got permission to use the inner harbour basin for diving shows. This activity did not offer an experience of the harbour as a biological habitat, but rather translated the water into a site for urban activities and urban living. Based on the public interest for the diving shows, the president of the diving association organised a signature campaign in support of a permanent diving and bathing facility. This was supported by the environmental mayor who succeeded to get the project into the municipal budget. In 2002 the first harbour bath opened.

Transition mediators

Embedded urban navigation is not coordinated by a shared vision, a shared strategy and transparent knowledge about other actor's manoeuvres. Such navigation is rather characterised by situated interpretations and responses to urban junctions. In order to understand how such myopic navigation may translate into a new socio-material logic, we introduce the notion of 'transition mediators'. A transition mediator is a project or intervention, which translates one or several junctions into a new socio-material logic, which redefines the existing boundaries of an urban sub-system. This is performed by a transition mediator through the reconfiguration of specific and dominant sets of cross-cutting associations among hitherto compartmentalised urban practices and infrastructures.

In the shift to the environmental preservation logic the biological water quality standard constituted the key transition mediator. This mediator provided a distinct technical vocabulary for how to understand the urban water recipients from a biological point of view. This vocabulary allowed for the generation of environmental data, which hence enabled the environmental perspective to be translated into strategic design criteria for the wastewater infrastructure. It also generated a biological representation of the harbour, which informed the vision of the 'harbour aquarium' in the late 1990s.

In the shift to the hygienic-recreational logic, the practice of harbour bathing has been the key transition mediator. Compared to the biological water quality standard the strength of this mediator lies in its ability to transcend beyond the technical realm of water professionals. As a mediator harbour bathing hence enacts a broad configuration of urban interdependencies by associating the hygienic water quality standard with the urban practice of harbour bathing. The hygienic water quality standard, on the one hand, enacts a series of interdependencies related to the design and performance of the wastewater infrastructure. The urban activity of harbour bathing, on the other hand, enacts a series of relations with the broader urban context; it provides value to the public, it provides a new design and planning perspective to architects and urban planners and it is used in the international marketing of Copenhagen. As a transition mediator the practice of harbour bathing hence re-defines existing urban orders among practices and sub-systems by configuring a wide set of association and reciprocities among the urban wastewater infrastructure, the harbour, the recreational practice of bathing, the strategies for urban development, and the marketing of Copenhagen as a green capital.

The capabilities of transition mediators in configuring new urban orders are however always incomplete. In relation the harbour bating an example is the emergence of new urban junctions in due to extreme rainwater events and flooding occurrence. It appears that harbour bathing practices is destined to enter into a conflict with the need to protect the city from flooding and thus allow sewage discharge in the harbour more often, especially in summer when extreme rain events are more probable. It will be interesting to see how new lines of embedded urban navigation will seek to resolve this junction in the coming years.

Conclusion

Our analysis of the harbour bath case suggests that the traditional layered conception of transition dynamics that identifies 'niches' or 'protected spaces' as the locus of transformational change (Kemp et al. 1998), may not necessarily be conducive for understanding the transition dynamics of urban contexts. Specifically our analysis questions the assumption that incumbent socio-technical configurations generate relatively cohesive "selection pressures" that prevent alternative configurations from emerging unless these are nurtured in shielded "incubation rooms" (Schot and Geels, 2008).

Rather our analysis suggests that urban contexts are likely to be characterised by multiple and conflicting "selection pressures". These multiple and conflicting pressures are generated as the practices and subsystem of the urban context interpenetrate each and generate a dynamic field of tensions, contradictions and ambiguities. To analytically highlight these tensions, contradictions and ambiguities within and among urban practices and sub-systems as an enabling condition for embedded urban navigation we have introduced the notion of junctions. The notion of junctions hence suggests that urban contexts are made up of a series of partly conflicting socio-technical arrangements, which are inherently unstable.

These junctions entail that urban contexts are characterised by myopic configurational 'repair work' aiming to continuously re-contextualise existing practices and subsystems in the dynamic and conflict-ridden urban context. We employ the notion embedded urban navigation to signify the combined strategic work of re-contextualizing and re-configuring practices and subsystem within a dynamic and conflict-ridden urban context. More specifically we argue that embedded urban navigation is related to junctions that provoke the stability of existing configurations of urban sub-systems. Finally, we introduce the notion of 'transition mediators' to understand how embedded urban navigation translates into a new socio-material logic. A transition mediator is a project or intervention, which translates one or several junctions into a new socio-material logic and thereby redefines the existing boundaries of an urban sub-system. We suggest that the strength and robustness of a transition mediator relies in its ability to cultivate cross-cutting associations and reciprocities that transcends beyond a single urban sub-system and a single professional realm.

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Transition Management and its democratic paradoxes: Principles and practices of democratic subversion in a Dutch city port

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Transition Management and its democratic paradoxes: Principles and practices of democratic subversion in a Dutch city port

Abstract

Various scholars have critically reflected upon transition management, some called for thinking beyond existing paradigms of democratic institutions and deliberative democracy (Hendriks, 2009; Voß, Smith & Grin, 2009). Taking up this challenge, this paper explores the fundamental democratic politics of transition management, both conceptually and empirically. To this end, it presents a 'post-foundational' understanding of democratic politics and compares it to other democratic models. Then, it explores transition management principles and practices of an empirical case in the Netherlands, a so-called 'Floating Communities strategy' as part of a sustainability transformation of the Rotterdam harbor area. The reconstruction of the design, planning and implementation of this strategy enabled a discourse analysis that assessed how this transition management case 'scores' in terms of different democratic models. A post-foundational approach on democratic politics not only shows how democratic practices play out in virtually all 'transition management steps', it also shows the inherent democratic paradoxes of transition management. It is argued that a post-foundational understanding of democratic politics can (and maybe should) inform transition management, both as a theory and a set of practices.

Keywords: transition management, democratic legitimacy, radical democracy, sustainable development, city ports

1. Introduction

This paper explores the democratic politics of transition management, both conceptually and empirically. Transition management, as a concept and a governance approach, has been adopted by the Dutch government. Various scholars have picked up this concept and critically reflected upon the transition management approach, its practice and its (broader) political implications. More specific, some contributions called for thinking *beyond* existing paradigms of democratic institutions and deliberative democracy (Hendriks, 2009; Voß, Smith & Grin, 2009). This paper takes up this challenge and explores what *fundamental* democratic tensions and challenges are involved in transition management theory and practices. For example, how do current voters and citizens relate to future generations (or non-citizens) in transition management practices ? What tensions between technocratic solutions and democratic inclusion do governing transitions trigger?

After reviewing literature on the governance of transitions in section 2, the paper zooms in on scholarly contributions that analysed the politics involved in transition management (section 3). Section 4 highlights the work of a selection of scholars that explored the democratic politics of transition management. Building on some suggestions and hints articulated by these scholars, section 5 presents a post-foundational understanding of democratic politics. Different from most scholars that investigate the politics involved in transition processes and practices informed by liberal political thought, a post-structuralist understanding of democratic politics calls into question the 'democratic nature' of democratic institutions and deliberative practices such as parliament and participatory processes (cf. Deveaux, 1999; Fritsch, 2002; Laclau & Mouffe, 1985: May, 2008; Rancière, 2004). This idea of democracy takes as its starting point conflict, disagreement and antagonistic relations, not consensus. This approach thus argues, that each institutionalised democracy or deliberative space contains undemocratic features. Section 5 also compares a post-foundational understanding of democratic politics with democratic models used by various transition scholars (aggregative democracy and deliberative democracy). Section 6 presents an empirical case of transition management practices in the Rotterdam harbour area (City Ports). The City Ports programme consists of five strategies that aim at strengthening the regional economic structure and becoming an attractive environment to work, sport and live in. This empirical section highlights one of these strategies: the Floating communities strategy. To reconstruct the City Ports programme and floating communities strategy discourse, data is derived from (policy) documents, websites in the programme. In order to focus on different democratic practices at different stages of the 'transition process' (not only formal decision-making), texts and images that reconstructed different actors, settings, events and sites have been central in the reconstruction. Section 7 looks at the transition management principles embedded in the floating communities strategy trough three conceptual lenses presented in section 5: aggregative democracy, deliberative democracy and post-foundational democracy. After reconstructing the strategic planning and implementation of the floating communities strategy, a discourse analysis assesses the democratic characteristics of the transitions management practices. Section 8, finally, returns to the central question of democratic politics in transition management and puts forward some points for discussion and future research questions.

2. Transition management: a prescriptive governance approach

Transition management has been (co-)developed and adopted by the Dutch government in 2001 (Kemp & Rotmans, 2009). The underlying idea of this approach is to move away from traditional planning and control policy and, in an alternative way, address persistent contemporary predicaments e.g. carbon-based energy systems, food security and quality, air quality in living environments and mobility problems in urban areas. This alternative is based on selecting particular actors (change agents, frontrunners, policy entrepreneurs) and engaging them in long-term strategic envisioning of sustainable imaginaries, mid-term tactical network formation, short-term operational experimentation and continuous reflexive learning (Loorbach, 2007). Transition management principles are grounded in complexity theory, reflexive governance, social theories and other theoretical schools (Loorbach, 2007, 2008-5). Transition management is presented as a prescriptive governance concept that enables contemporary governments and social actors to engage in complex problems they face (of framed as 'sustainability challenges') in a somewhat unconventional manner. As such, transition management can be seen as a particular approach within the wider field of transition studies, using a particular set of assumptions and concepts (Markard et al., 2012; Lachman, 2013).

Transition management "conceptualizes the role of agency in transitions and can be used to analyze possibilities for influencing. Transition management therefore necessarily builds on an understanding of transitions from a complex system perspective as basis for development of governance strategies"(Loorbach 2007:18)[1]. In other words, managing, governing or steering transitions is understood in direct relation to a transition perspective. "The basic steering philosophy underlying transition management is that of anticipation and adaptation, starting from a macro-vision on sustainability, building upon bottom-up (micro) initiatives, meanwhile influencing the meso-regime. Goals are not fixed but developed (through a search and learning

[1] I mainly refer to the work of Derk Loorbach, since he developed the idea of transition management quite systematically (Loorbach, 2007).

process) by society and the systems designed to fulfill these goals are accordingly created through a bottom up approach using incremental steps directed toward a long-term goal (e.g. directed incrementalism (Kemp 2003)) (Loorbach 2007: 81)". Transition management, then, is an ambition approach that is both hands-on and hands-off. This means that direct control becomes indirect influence, and predicting 'the actual future' turns into experimentally exploring 'different futures'.

The broad field of complexity sciences has indeed informed the concept of transition management. The notions co-evolution, self-organization and emergence play a central role in some of the principles underlying transition management. "Co-evolution (…)refers to the path dependence that arises from mutual adaptation between system components and between system and environment" (Loorbach, 2007: 56). Co-evolution between complex systems lies at the heart of grasping the interactive logic between multiple societal levels and domains. Self-organization can be understood as the emergence of order without external control (Nicolis, Prigogine, 1989). This is highly relevant, as innovative and new agenda's and ideas for change might occur beyond institutionalized structures and practices (in so-called 'niches'). Emergence, formulated straight forward and simple, refers to the upcoming of new patterns (ibid). This also implies that new patterns may become more and more visible and normalized at a higher level in society. Co-evolution, self-organization and emergence, then, are very much interrelated. All three are core ingredients for transformative processes. What is more, there are additional notions from 'complexity theory' that have informed the transition management approach, such as variation and selection, feedback and attractors. By yielding a variety of agenda's and future scenario's, and by constantly selecting and reflectively learning from these sections (feedback), one is able to experiment with new attractors in existing social contexts and institutional settings. Transition management, as a normative approach for socio-political action, can be characterized by:

- Multi-actor decision making;
- Long-term, collective goal setting and anticipation;
- Agenda-building;
- Experimenting and innovation;
- Evaluation, adaptation and reflexivity;
- Knowledge diffusion and learning (cf. Loorbach 2007:87).

Loorbach developed the idea of transition management into an operational model that consists of four (interrelated) building blocks:

1. *Strategic: Problem structuring and envisioning: establishment of a transition arena*

   A key issue at the strategic level is the problematisation, which leads to a "shared conceptualization of the system at hand and the problems it is confronted with, and thereby also create a stronger sense of urgency to act. This broader, systemic conceptualisation and 'problematisation' of a societal problem provides the basis for reframing a societal problem and thus for developing new solutions and strategies" (Loorbach, 2007: 116). This 'step' is highly relevant as it enables actors to reflect on the very necessity and significance of perusing a transition in the first place.

2. *Tactical: Development of sustainability images, pathways, and a transition agenda*

   This change in perspective, captured in the new discourse that is able to create transformative change at a systemic level, should be further translated to and made concrete within various networks, organizations and institutions at a less abstract level (Loorbach, 2007: 117). This means making tactical connections with specific organizations and actors that share a similar sense of urgency and are willing and able to further the ambition of realizing a (desirable) transition.

3. *Operational: Initiation and experiments of transition experiments and mobilization of actors*

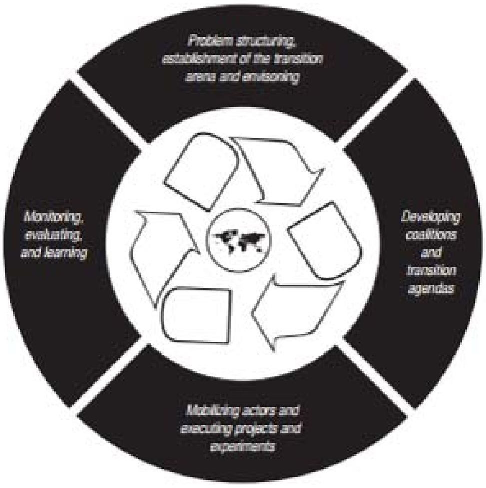
   This operational level of transition management has the ambition to create spaces for niches and alternative ideas and practices. As Loorbach (2007: 122) describes it: "Part of the strategy is to involve a broad array of individuals and organizations, even citizens in general, in various forms: through debates, concrete projects, through communication, events, by drawing attention to individuals' initiatives and by calling on people's own responsibilities regarding sustainable development".

4. *Monitoring and evaluating the transition process*

   Reflection is a key element in managing transition. This enables one to observe unforeseen consequences and contextualize one's own role. This dimension of "evaluation and adaptation is (…) an explicit part of the transition management model and is used to stimulate modulation and further refinement of the transition management activities at all levels" (Loorbach, 2007: 123).

These four 'steps' can be visualized as follows:

Figure 1: Transition management cycle



A core notion in TM is the so-called 'transition arena', as it embodies these four building blocks. A transition arena can be defined as: "an innovative participatory process of envisioning, searching, learning and agenda-building aimed at social learning as a means to achieve (sustainable) social change" (Loorbach 2007: 44). It is a particular site in which the practice of managing transitions takes place. These arena's should be understood as a model, they can be connected to a specific sector (mobility, or health), to a region or to another system. However, it remains crucial that *fundamental change* is part and parcel of the process and should be engrained in all the transition management activities.

3. Transition management and its (democratic) politics

Recently, different scholars have critically reflected upon the transition management approach and its broader political implications. For example, Shove and Walker claim that transition management needs to explicate its "obscure politics" because of: (1) the high level of abstraction in its theories and practice ('systems', management of the 'it'); (2) the unknown institutional side-effects of managing transition; and (3) the unclear role of the vague and depoliticised notion of 'sustainability'. They also (argue that "there is a politics to transition management, a playing out of power of when and how to decide and when and how to intervene, which cannot be hidden beneath the temporary illusion of 'post-political' common interest claims of sustainability (Swyngedouw 2006) (2007: 5)". Smith and Stirling state that it "is unclear how transition management processes sit in relation to prevailing policy institutions and political activities" (Smith & Stirling, 2010: 9). And as Kern argues: "If transitions are to a large degree political processes resulting from decisions by multiple actors, then political dimensions should be at the heart of the analysis" (2009: 26). Similarly, the unclear meaning of the political aspects of sustainability transitions and their management is articulated by Verbong & Loorbach stating that experiments related to transition management, strategic niche management, transition monitoring innovation systems "raise questions about and prompt debate in the scientific arena (for example related to normative orientation of researchers, legitimacy of interventions and lack of attention to power and politics), and in turn lead to adapted and new strategies" (Verbong & Loorbach, 2011: 16). This paper focuses on of the key political bottlenecks of TM, i.e. its relation to the notion and practice of *democracy*.

Research on the governance and politics involved in transition management has called for thinking *beyond* existing paradigms of democratic institutions and deliberative democracy (Hendriks, 2009; Voß, Smith & Grin, 2009). Scholars that actually address the linkage between TM and democratic politics, problematize its temporal dimension. That is to say, they highlight the conflicts and tensions that emerge between planning embedded in (traditional) democratic institutions and reflexive governance that is linked to sustainability-led and long-term transformations. I briefly discuss two contributions that centre-stage the democratic politics involved in transition management (Hendriks, 2009; Voß, Smith & Grin, 2009).

4. What does 'democratic transition management' mean?

Hendriks discerned three democratic storylines in the Dutch Energy Transition discourse. The dominant storyline was a technocratic-managerial or elitist understanding of democracy (a transition 'for the people') highlighting innovation and socio-technical solutions. The two other storylines were 'more' democratic; a representative democratic approach by which experts advise elected politicians and authorities; interest group pluralism/neo-corporatism based on the representation and participation of 'relevant stakeholders'. All storylines refer to a specific understanding of democracy providing specific criteria to assess how democratic a transition, and its management, actually is. Consequently, Hendriks' analysis showed that steering of (socio-technical) transitions downplays certain democratic principles. Hendriks proposes to understand 'transition networks' in relation to 'network governance', rendering visible the democratic tensions between everyday practices in transition network and representative institutions (Hendriks, 2009: 257-258). So, transition management practices (e.g. selective participation, organising arena's, assessing experiments) have uneasy relationship with different democratic models. Hendriks argues that "[t]hese storylines will need to be expanded if we want democratic considerations such as legitimacy and accountability to be taken seriously in transition processes" (Hendriks, 2009: 358). For Hendriks this means that "arguments in favour of democratic transition management may need to be couched in epistemic terms, for example, by arguing that more inclusive and diverse participations can potentially capture more knowledge for innovation". To this end "more discursive and agonistic (conflictual) versions of democracy, networks might deepen democracy (see Dryzek, 2007; Sørensen and Torfing, 2007). For example, networks could open issues up to new participants and ideas (Wätli et al., 2004), and if radical enough, they might even foster pluralism and dialogue (Bevir, 2006) (Hendriks, 2009: 357)". Hendriks proposes to engage in more *polycentric democratic landscapes*, referring to the fractured and dynamic character and sites of democratic deliberations and political decision-making. Three types of solutions put forward by Hendriks are to: 1) explicate linkages between official democratic representations and transition networks; 2) to include a wide variety of elites, institutions, actors and material things in the political process; and 3) to foster the public character of transitions and long-term politics.

A similar argument has been made by Voß, Smith & Grin (2009). These scholars also thematised democratic politics of TM in terms of long-term policy and share much of Hendriks' arguments. For them "[t]he difficulty to help 'rational discourse' to unfold and prevent it [TM] from corruption is of general interest when it comes to enriching representative democracy; especially with a view to mitigate myopia and sectoralization. Finding adequate ways to embed long-term policy design in a (changing) framework of democratic institutions is an important area for future conceptual and practical thinking" (Voß, Smith & Grin, 2009: 287). They, for example, state that alternative democratic practices should be facilitated by convening "different transition arenas for dissenting voices, rather than [to] get everyone around the same table" (Voß, Smith & Grin, 2009: 293).

So, having put democratic politics on the agenda of transition studies, these scholars address a key political issue in transition management. Hendriks and Voß et al. propose alternative frameworks and argue that democratic transition management should engage in a 'polycentric democratic approach' to enable the interaction between different types of democratic representation and deliberation in the context of (long-term) societal change. Even though these scholars hint at alternative democratic models (e.g. 'discursive and agonistic (conflictual) versions of democracy', 'politics of things', Hendriks, 2009), this 'alternative' (and its relation to other democratic models) has not been explored yet. In this paper such an alternative is proposed, compared to other forms of democratic politics and investigated in an empirical case of transition management. The contributions of Hendriks and others in the context of 'democratic transition management' bear at least two weaknesses. First, even though transition management is aimed at 'regime shifts' and 'radical change' most democratic models rely on representation, participation and stakeholder involvement of *institutionalised democracy*. To think about Hendriks' 'polycentric democratic landscapes' then, should at least try to move away from thinking in terms of static systems vocabulary (such as input, output legitimacy). Second, and related to the first weakness, the historical and ideological background of most democratic conceptions are rooted in *Western liberal political thought*. This is not problematic in itself, to be sure it is part of an intellectual tradition and historically developed socio-political organisation, but thinking in terms of representation, participation and deliberation brings with it downsides. To understand broader societal changes in contemporary society cannot be isolated from the underpinnings of the socio-political traditions, state formation and liberal overtones embedded in various (liberal) democratic models. In other words, to understand fundamental change today should be linked with fundamental changes in how we perceive and practice democracy.

5. An alternative model: post-foundational democracy

The 'alternative model' of democratic politics presented here is *post-foundational democracy*, which moves away from liberal democratic theories (e.g. representative democracy, pluralist democracy, deliberative democracy). Post-foundational democracy (which resonates with radical or democracy agonistic democracy) calls into question the 'democratic nature' of democratic institutions and deliberative practices such as parliament and participatory processes (cf. Deveaux, 1999; Fritsch, 2002; Laclau & Mouffe, 1985: May, 2008; Rancière, 2004). Post-foundational democracy can be contrasted to other paradigms in democratic thought. In this paper, following Hendriks and others (see above), post-foundational democracy is contrasted with roughly two dominant democratic models in the tradition of liberal political theory: *aggregative democracy* (developed by Schumpeter, Dahl and Downs, all highlighting quantity, e.g. majority voting) and *deliberative democracy* (advanced by Cohen and Habermas, highlighting accessibility and the quality of a debate, e.g. participatory processes). The idea of post-foundational democracy takes as its starting point conflict, disagreement and antagonistic relations, not consensus (not only short-long term tensions). This approach thus argues, that each institutionalised democracy or deliberative space contains undemocratic features. 'Consensus', 'agreement' or a 'win-win solution' might sound democratic, but are also exclusionary. A crucial insight of post-foundational democratic politics is to always stay open for 'the unknown' and 'otherness', so as to suspend closure, hierarchy and power relations that emerge when criteria are formulated and decisions are made. Post-foundational democrats would agree with aggregative democracy that all members of a political community are equal, but they are equal because of their difference. Not one voter is the same. What is more, by aggregating the *demos* in this way, the non-demos is excluded (people that do not have voting rights, illegal immigrants, animals, even material objects, etc.). The same holds for critique against deliberative democracy. Post-foundational democracy agree with deliberative democrats that the political sphere (of the state) does not coincide with the public sphere, but argues that the very criteria for rational deliberations and public debates (e.g. in Habermas' ideal), supposes that all individuals are accepted as equals in public discourse (Kelly, 1994). In fact, every institution, social organisation and network is historically contingent and carries implicit normative and political assumptions about what is proper, what is a rational argument, what is democratic, who should speak, what is expected to be said and who counts as a speaking subject (e.g. voter),etc. So, all institutions, ideals and forms of organisations that present themselves as democratic, have traces of undemocratic power relations, i.e. they rely on certain differences, certain exclusions of some people, norms and voices. This understanding of democracy is based on a different understanding of politics (an a-liberal understanding of politics). Jacques Rancière calls the networks of instituted norms (even democratic norms) not politics, but the police:

> "Politics is generally seen as the set of procedures whereby the aggregation and consent of collectives is achieved, the organization of powers, the distribution of places and roles, and the systems for legitimizing this distribution. I propose to give this system of distribution and legitimization another name. I propose to call it the police" (Rancière, 1999: 28).

For Rancière, politics is something else. It refers to the un-institutionalised parts of and their insistence on social organisations.

> "I now propose to reserve the *politics* [for] whatever breaks with the tangible configuration whereby parties and parts of or lack of them are defined by a presupposition that, by definition, has no place in that configuration [created by the police] – that of the part of those who have no part (Rancière, 1999: 29-30).

This understanding of politics is thematised by different advocates of radical politics. Lefort argued that democracy is 'an empty place' that should always by empty to be democratic (Lefort, 1986), Derrida highlighted the virtual and ever sliding nature of democracy as 'a promise', i.e. 'democracy to come' (Derrida, 1992). Other labels, such as radical democracy and agonistic democracy, in different ways refer to the inherently political nature of every form of democratic organisation and institution. In this sense, post-foundational democracy centre-stages conflict, tensions and insurgent directed towards social change (e.g. Mouffe, 2000).

For the sake of clarity, the different democratic perspectives can be contrasted as follows.

Figure 2. Overview of perspectives on democratic politics

	Aggregative democracy	**Deliberative democracy**	**Post-foundational democracy**
Understanding of *demos*	Aggregated *demos* (one man one vote) Voter, citizen, elected politician	Deliberative *demos* (everyone should be able to deliberate equally) Participant in public debate, fora and informal networks	Coming *demos* (*demos* that is not included in democratic institutions and debate) Activist, resisting closure, political membership and institutionalisation

General principles	Equality among *demos* should be central in decision-making (political membership) Quantity of political community (everyone is equal, everyone has equal vote)	Accessibility and equal recognition of *demos* should be central in deliberation Quality of democratic debate (rational arguments, *agora* should be open for everyone)	Inequality and disagreement among *demos* should be central Impossibility of democratic institutions and debate (institutions and *agora* are historically contingent and undemocratic)
Democracy and forms of rule	Democracy is a form of rule (self-government) that centre-stages the demos, a political community that rises above any other form of rule (technocracy, autocracy, etc.)	Democracy is a form of self-government that does not coincide with the formal political sphere (state, institutions) but relies on rational communication in the public sphere	Democracy is an ideal and a promise, a principle to resist any form or rule and instrumental knowledge, hierarchy and institution(alisation), to remind institutions of their impossibility. This understanding of democracy is directed towards fundamental change of institutions and social organisation

These difference should clarify how these democratic models actually differ. The introduction of the notion post-foundational democracy should be able to assess what *fundamental* democratic tensions and challenges are involved in transition management theory and practices. For example, how do current voters and citizens relate to future generations (or non-citizens) in transition management practices? What tensions between technocratic solutions and democratic inclusion do governing transitions trigger? The next section explores and compares these differences in the context of an empirical case of transition management practices.

6. Democratic transition management in practice: The Dutch Floating Communities case

This section presents a strategy called 'floating communities strategy', embedded in a broader programme called City Ports aimed at transforming the Rotterdam harbour area towards sustainability. Given that the programme explicitly refers to transitions and has adopted some transition management principles, the floating communities strategy can be seen as a network of transition management practices. It should be noted that it is virtually impossible to discern transition management practices from other activities, as they often merge and intersect with other discourses and types of planning, governance and social activities. In order to explore democratic politics involved in this case of strategy, I reconstructed the 'floating communities discourse', as part of the broader Stadshavens discourse, by focusing on texts and images (legal texts, policy documents, websites, brochures, etc.) and doing discourse analysis. As discussed in the introduction, this enabled me to unravel how different democratic models were embedded in the transition management discourses and practices in virtually all phases of the 'transition process' (different actors, settings, events and sites).

The context: Stadshavens Rotterdam

In the harbour area of the Dutch city of Rotterdam (which is about 1600 hectares), a set of innovative projects and new initiatives has emerged under the label "City Ports" (in Dutch *Stadshavens*). The Stadshavens programme has a long and complex history. Different policies, local and national developments intersected in the 2000s. Different plans for the expansion of the harbour intertwined with the aim of creating a more environmental friendly and sustainable city (Rotterdam suffers from high rates of CO2 emissions), safeguarding economic activities, spatial development and housing plans (Daamen, 2010). In 2008, the city of Rotterdam Council and the Port of Rotterdam Authority formulated a strategic vision and an implementation program to transform the Rotterdam harbour area. The main objectives of the transformation program are strengthening the economic competitiveness and providing a more attractive, high quality living and working environments (Project bureau Stadshavens Rotterdam, 2008: 2). Some of the challenges that have created the need for this program are: climate change, land scarcity, urban CO2 emissions, maintaining international competition of Port of Rotterdam, increasing population density and lack of proper accessibility and integrated mobility systems. The vision for regenerating the Rotterdam city-port nexus is presented as both a matter of 'urgency' and 'opportunity'. To this end, some legal requirements and regulatory procedures were bypassed in order to create space for experimentation. This exception was made possible by the so-called Crisis and Recovery Act[2]. Additionally, knowledge institutes were involved in the design and creation of specific buildings and constructs (e.g. RDM Campus, Hogeschool Rotterdam, Alberda College)[3].

The Stadshavens Rotterdam website states that it "wants to develop into a quality port and an excellent location, not only for port and transport related industry, but also for innovative businesses and knowledge institutes. Rotterdam is also creating an image of itself as a trendsetter in the fields of sustainable energy and climate adaption, with the aim of attracting professionals and pioneers keen to try out these new trends. Stadshavens can provide them with everything they need for setting up their businesses, along with exceptional residential developments, cultural amenities and good educational facilities"[4]. The program is targeted at four geographical districts and substantiated by *five strategies*[5]:

1. Reinventing delta technology: providing space for experimentation and innovation for energy transition and water management (e.g. for an energy neutral city-port nexus);
2. Volume & value: optimising existing space through innovative logistics for industrial growth and more space for environment and landscape;
3. Crossing borders: (re-)connecting city and port both physically and socially (e.g. by providing cultural and sport facilities near the water);

[2] In 2007, the minister of Infrastructure and Environment commissioned a working group to investigate why infrastructure projects take 'so long' from design to implementation and how these processes could be realised faster. In 2008, commission Elverding published a report that diagnosed the 'slow process' and proposed a set of solutions. The main problem was located in (1) preparatory work and administrative culture; (2) the design of the governance process; and (3) legal aspects[2]. The key problem with the 'old approach', which takes about 14 years on average (from design to an implementation decision for an infrastructure project) concerns 'legal and administrative barriers' including among others too many EU environment regulations, and erratic processes with changing plans and perspectives. The Crisis and Recovery Act was politically and legally accepted by referring to deal with the economic crisis. As former PM Balkenende argued in 2010: "*We are in the midst of the most severe economic crisis of the last decades. We cannot fall asleep by messages that say the worst part is over. Many negative effects, especially regarding employment, are coming our way with full force. The government believes in a common responsibility of government and parliament, to work on a sustainable recovery and on measures to keep employment on the right track"* (Source: Eerste Kamer (Senate document), 2009–2010, 32 127, C., 9.).

[3] For an extensive reconstruction of the emerge of the Stadshavens programme, see Daamen, 2010.

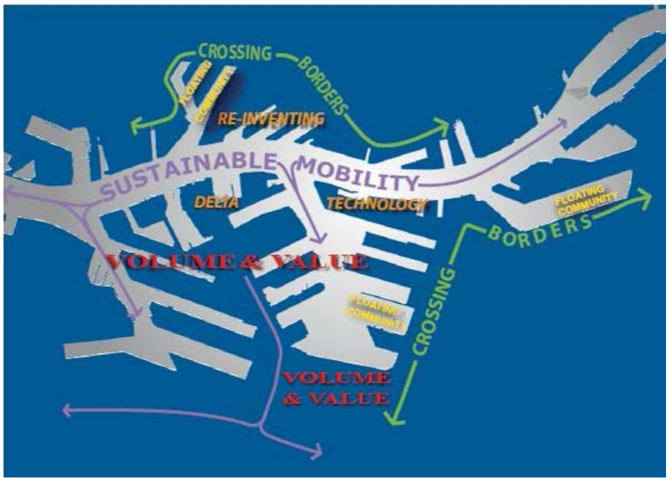
[4] Source: http://stadshavensrotterdam.nl/eng/vision.

[5] Source: Programmabureau Stadshavens Rotterdam. (2008). Stadshavens Rotterdam 1600 ha. Implementation Programme 2007-2015. Rotterdam: Programmabureau Stadshavens Rotterdam.

4. Floating communities: creating floating housing, workplaces, recreation facilities to land scarcity and withstand climate change, also restructuring the urban economy and creating new social networks;
5. Sustainable mobility: creating a multi-modal system of mobility that also connects public transportation on land and water.

These strategies are envisioned spatially as follows (Project bureau Stadshavens, 2008a: 7).

Figure 3. Spatial image of Stadshavens strategies



Floating Communities

I discern two 'phases' of the floating communities strategy, resonating with the strategic organisation of the Stadshavens program: 1) envisioning and planning a strategy for Stadshavens); and 2) implementing a strategy for Stadshavens. Differentiating envisioning from implementation is a well-known approach in strategic planning. The end of this chapter highlights the transition management principles related to this strategy.

Strategic vision for Floating Communities

The strategic vision for the Floating Communities strategy is framed in relation to the fact that "on third" of the port area consists of water. Water, the vision states "gives the city life its own unique character" (Project bureau Stadshavens, 2008a: 14). The potential of unused spaces of water is highlighted: "Basins where port industry has moved away are ideal locations for floating housing and workplaces. This will further enhance the quality of Stadshavens Rotterdam and benefit all the residents of Rotterdam" (ibid). Some pictorial examples of how some elements of the floating communities might look like[6]:

Figure 4. Imaginary of floating communities

These images are supported by arguments about what these floating buildings will actually do. "Floating constructions, like work spaces and pavillions, serve as boosters for development. Floating restaurants and other public facilities will be the centre of attraction in the Rijnhaven". (…) "There's a superb view from the many footpaths and cycle routes along the waterside, which pass by cultural attractions, floating cafes and restaurants and watersports facilities, including an open-air swimming pool" (ibid). On the Stadshavens website the main idea of the floating communities strategies is presented as follows:

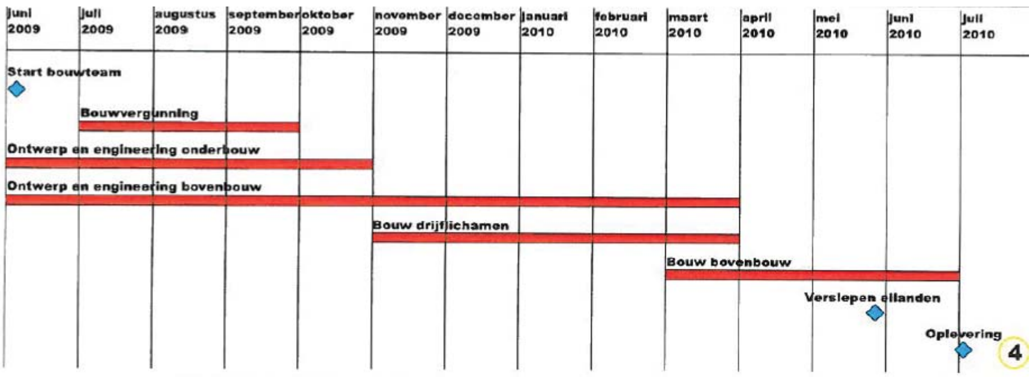
> *"Space will become available in Stadshavens for 5,000 homes on or beside the water. This extraordinary residential environment should attract professionals and pioneers[7] who want to stand out from the crowd. These people are needed to inject new life into Rotterdam's economy. The SS Rotterdam, a floating complex of conference, leisure and catering facilities, will be the first step in the process"[8].*

Next to these direct references of the strategic vision in policy documents, a variety of other discourses are intertwined with this future image. Two architects bureau's (Public Domain

[6] Project Bureau Stadshavens, 2008a: 15.
[7] In Dutch the word 'hoogopgeleide groepen' is used, which literally means 'higher educated groups'.
[8] See: http://stadshavensrotterdam.nl/eng/floating-communities.

Architecten and Deltasync) designed the floating pavilion (bubble structured construction, see left picture). This floating pavilion that was produced sustainable served as an experiment and a show case and had to be designed within one year. Planning and realising this part of the floating communities strategy was visualized in a brochure of Public Domain Architecten. Some exemplary pictures of these activities[9]:

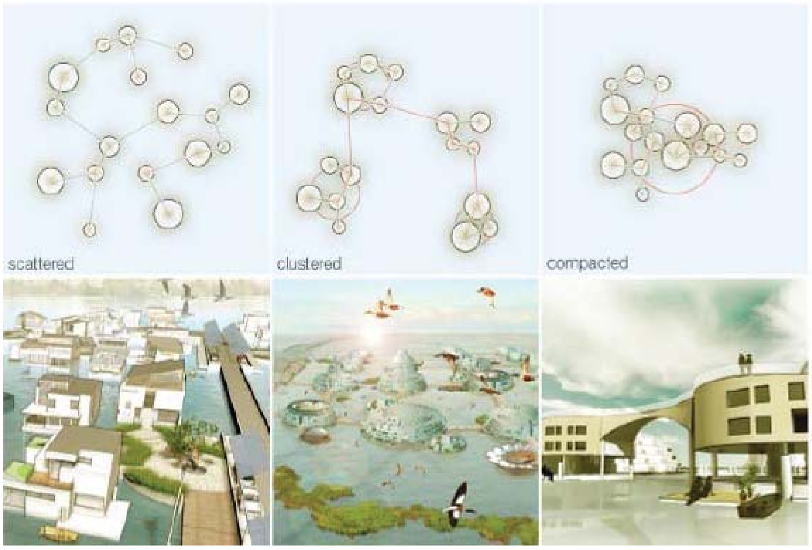
Figure 5. Imagining and planning floating communities



A number of organizations co-produced a brochure about the floating cities (Delta Synch, 2008: 9). This brochure nicely mentions how different urban design concepts relate to different images of a future floating city[10].

[9] Brochure of Public Domain Architecten.
[10] Brochure of Urgenda about 'the Floating City', 2008.

Figure 6. Urban design concepts of floating cities



This picture is accompanied by a text: "Different town planning typologies are conceivable varying from a compact core to more dispersed configuration. Investigating the two extremes reveals how density affects infrastructure and spatiality. A compact city needs fewer infrastructures but the sense of space and contact with the water are more limited. This is the opposite for a dispersed model where spaciousness comes at the cost of more infrastructures. The dynamic nature of the Floating City makes it possible to begin with a dispersed plan and to develop this further into one or more centres. The best possible use of the available water surface is thus continually achieved" (ibid)

Implementation programme of Floating Communities

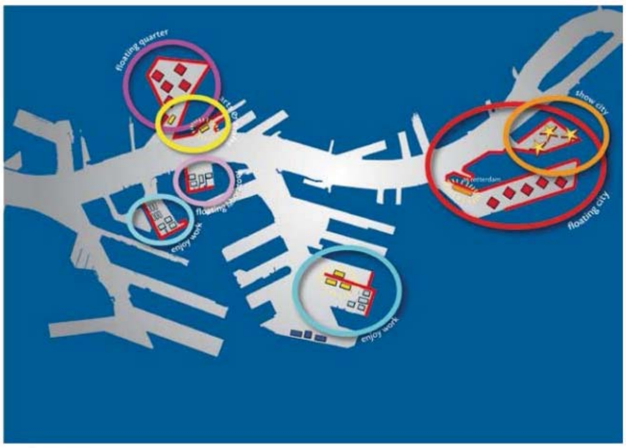
It is instructive to present some exemplary statement about the floating community strategy as articulated in the Stadshavens Implementation Plan 2007-2015:

1. "Rotterdam could make a name for itself with floating residences on tidal waterways in a number of Stadshavens outside the dikes. Recent research has shown that there is significant market potential for this sort of housing. Its special appeal could persuade highly educated people to stay in Rotterdam, as well as attracting new people from elsewhere. These groups are important for restoring Rotterdam's economy" (2008b: 17);

2. "Pioneers will want to come and distinguish themselves from the masses, people will come to eat, play sport or sleep on a floating facility and businesses will set themselves up on a floating work island. Floating construction can therefore provide a boost for the development of the area" (2008b: 17);
3. "The development of the districts will create a sustainable transition for Stadshavens. The City Council, the Port of Rotterdam Authority and the State are putting together a strategy for sustainability, which should help to resolve any conflicts arising where living and working environments converge (Project bureau Stadshavens, 2008a: 4)".

The implementation of the floating communities strategy is also supported by imagining where (geographically) the floating constructions should actually be build. Consider, for instance, the image of floating communities in the Stadshavens implementation programme (Project bureau Stadshavens, 2008a: 17):

Figure 7. Spatial imagination of floating cities



Floating Communities

One of the most concrete examples of the implementation of the floating communities strategy is the actual construction of the floating pavilion. Some actual pictures that signify parts of the building process (2009-2010)[11]:

[11] See also the website of the floating pavilion: http://www.drijvendpaviljoen.nl/.
Sources of the images: http://www.starflood.eu/cities-and-rivers/rotterdam/,

Figure 8. Building the floating community strategy

Transition management and the floating communities strategy

Now that the floating community strategy discourse has been reconstructed (its basic aims, ideas and practices), we are able to identify the transition management principles (see section 2). This permits us to, in the next section, assess the democratic politics of these transition management practices embedded in the floating communities strategy. Even though there is no 'pure' transition management project, it is always context specific, adapted and adopted locally (Loorbach, 2007), some of the transition management principles can be discerned.

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http://www.rotterdamclimateinitiative.nl/nl/100_klimaatbestendig/projecten/drijvend_paviljoen_in_rotterdam_centrum?portfolio_id=19, http://www.sustainablebusiness.com/index.cfm/go/news.display/id/24443.

Figure 9. Transition management and the floating communities strategy

	Floating communities strategy
Strategic level: Problem structuring and envisioning, establishment of a transition arena	Rotterdam Council and the Port of Rotterdam Authority authorised the programme. A Crisis and Recovery act circumvented some legal requirements and procedures, in order to justify experimentation. The projectbureau Stadshavens was responsible for and facilitated the future strategic envisioning. Strategic visions were produced by architects and graphic designers (from Public Domain Architecten and Deltasync).
Tactical level: Development of sustainability images, pathways	The project bureau Stadshavens together with architects, (visual) designers, educational organisations create the images of how floating buildings, sport facilities and other activities
Operational level: Initiation and experiments of transition experiments and mobilization of actors	A floating pavilion is build as an experiment and to set an example for other floating units (in the end, 5000 homes for professionals) by professional builders
Monitoring and evaluation the transition process	The floating pavilion, its effect and the broader floating communities strategy is (expected to be) monitored by the project bureau Stadshavens, authorised by the Rotterdam Council and the Port of Rotterdam Authority

7. Democratic politics in the floating communities strategy

Now that we have reconstructed the transition management cases (floating communities strategy), let's return to the democratic politics involved in transition management. If we look at the three democratic perspectives presented in section, we can identify the democratic politics of the transition management practice embedded in the floating communities strategy.

Figure 10. Democratic politics of transition management in the floating communities strategy

	Aggregative democracy	Deliberative democracy	Post-foundational democracy
Strategic level: Problem structuring and envisioning	Democratic, because the overall Stadshavens programme was authorised by the democratically elected local government and council. The *demos* is represented in this democratic institution. Crisis and Recovery Act was also democratically approved.	Somewhat democratic, even though the Stadshavens programme was authorised by the democratically elected local government and council, there was little deliberation between in the public sphere (outside formal state institutions) about what was actually the problem and what the future of the Rotterdam harbour area (including its water) should look like. Even though non-state actors were involved (City Port organisation, knowledge institutes, architects), broader public debate and deliberation about the programme seems to be absent. The fixed goals of economic development, housing on water were not discussed in broader public settings.	Undemocratic, even though the Stadshavens programme was authorised by the democratically elected local government and council, legal space was created that bypassed democratic accountability. Unconventional building concepts were used directed towards social change, however, the buildings were mostly build for well-educated professionals. At the outset, a set of goals (economic development, using water as land, sport and leisure activities, etc.) was formulated. Little to no space was created (yet) for critique, opposition and radically altering the floating communities strategy (and the Stadshavens programme more generally)
Tactical level: Development of sustainability images, pathways	Same as strategic level	Same as strategic level	Undemocratic, specific design concepts were made and used based on specific knowledge. The meaning, identities and practices that

			were ensured by the floating communities were meant for a specific selection of people (well-educated, sport, Rotterdam residents, etc.) at the expense of non-Rotterdam residents, lower income groups, non-sport/leisure activities, animals, letting water be water, etc.
Operational level: Initiation and experiments of transition experiments and mobilization of actors	Same as strategic level	Same as strategic level	Undemocratic, a specific meaning of floating communities was installed, a specific type of human populations, excluding other meanings and (experimental) possibilities at that very geographical site
Monitoring and evaluation the transition process	Same as strategic level	Same as strategic level	Undemocratic, because the monitoring and evaluation criteria are set by a specific organisation (Stadshavens project bureau) with a specific and institutionalised understanding of the *demos*

Four comments should be made here. First, it is clear that the different have democratic models imply very different things. Whereas aggregative democracy argues that basically all ideas and actions of the Stadshavens project bureau are democratic, given the authorisation of the democratically elected local government (even the legal exception), deliberative democracy argues that the lack of public debate downgrades the democratic quality of the design and implementation of the floating communities strategy. A post-foundational democratic view provides us with a different picture. Contrary to the other two models, who argue that there is some sort of democratic anchorage, post-foundational democracy argues that every planning and strategy (how democratic and collectivist they may look like or sound ('floating *community*'), depends on the exclusion of certain aspects. Second, the aggregative and deliberative democratic perspective have a specific understanding of democracy, having the capacity to assess the democratic character of all transition management aspects/levels. Even though each level can be further nuanced and specified based on more empirical material, the post-foundational democratic view offers a nuanced and specific elaboration of how (un)democratic specific procedures and practices actually are in view of broader political and ideological discourses. Third, it should be noted that the floating community strategy also contains democratic traces from a post-foundational democratic viewpoint, given the ability of floating constructs to change and adapt depending on circumstances and new problems. This, indeed, resonates with some elements of post-foundational democracy (to always stay open for a new *demos*, relations and values; 'democracy to come'). Fourth, this empirical case is very specific and closely related to formal state institutions. A different case, more remote from formal democratic institutions, could result in a different image of the democratic politics involved in transition management (e.g. associative democracy, Hirst, 1993).

8. Conclusion and discussion

This paper explored the democratic politics of transition management, both conceptually and empirically. After reviewing existing literature on transition management and its politics, the paper presented a perspective of post-foundational democratic politics. Based on this perspective, and other democratic models, an empirical case of transition management practices was explored. This empirical analysis illustrated that transition management contains both democratic *and* undemocratic principles, depending on one's understanding of democracy. The empirical case showed that some decisions indicate breaking out of existing structures and institutions (e.g. using unorthodox design concepts, underscoring adaptability of floating houses, temporarily bypassing environmental and safety regulations) and other highlight sticking to dominant frames of reference (e.g. formulating clear economic objectives, seeking approval from democratic institutions, framing floating houses as a growth market). This elucidates *that* and *how* transition management is inherently ambiguous in terms of its 'democratic character'. In that, different understandings of the *demos* exist (e.g. future/current populations, residents/voters/employees/consumers, human/non-human populations, material and geographical spaces), different types of democratic principles seem to be intertwined (aggregation, deliberation, resistance) and boundaries between different forms of rule are entangled (democracy, technocracy and bureaucracy). It is interesting to note that this particular transition management context not only bypasses specific environmental and safety regulations, but also circumvents broader democratic debate and propose market-based solutions and technocratic rule. Consequently, the floating community strategy, and the Stadshavens programme more generally, seems to resonate with what Kenis and Mathijs called the post-political character of transition management (Kenis, 2012). Paradoxically, the floating community strategy breaks with existing structures and relations (familiar building concepts, safety regulations, the link between humans and their living environment, etc.), resonating with some of the principles of post-foundational democracy (social change and seeking new identities and social relations).

The notion of post-foundational democracy does not only productively resonate with the conceptual and normative orientation of transition management (e.g. on transformative change, flexibility, experimentation) (Loorbach, 2007, Hendriks, 2009), it also enables us to elucidate democratic politics every step 'transition managers and practitioners' take. This also prompts new theoretical and empirical questions about who counts, and when and where they count in view of transition management politics and contemporary sustainability challenges. Future research should further such questions and compare different transition management context, not only differing in terms of relative distance from state institutions, but also different national/regional contexts.

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Copenhagen's Metro: a sustainable transitions analysis

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Introduction

In 2002 began operation the first phase of the fully automatic Metro of Copenhagen. By 2007 the third phase was completely and the Metro was effectively connecting the west of Copenhagen with the new town Ørestad and the airport. Today is under construction the fourth phase of the system, which is a city ring, aim at enhancing public transportation in the inner city of Copenhagen. The Metro has been the result of a long process which began in 1989 and included the following sustainability concerns shared among politicians and experts at the city and the country level: there was a recognized need to invest heavily in the central areas of Copenhagen to combat the degradation of the previous decades; there was strategic interest at the city and national level in supporting a centre oriented growth and renovation in the capital of Denmark; and third, there was the motivation of supporting public transportation instead of private motorised transportation. The research questions to be addressed in this analysis are: to what extent is the Metro of Copenhagen an innovation from a sustainable transitions perspective? And, has the Metro delivered what was expected from it?

Our analytical point of departure is a theory of arenas of development (Jørgensen, 2011). This theory is a flat approach that does not make any a priori assumption about the nature of involved actors and influences. Instead it traces the actions actors perform and aims at understanding how they build alliances, alignments and agreements to produce change. Their work also involves dynamics of interrupting existing relations and managing influences at various local, national and international levels. This approach is critical of the multi-level perspective (Geels and Schot, 2007), which proposes an a priori differentiation between niche, regime and landscape levels. From an arenas perspective, innovations are the work of actors who successfully manage and work on relations of different natures. For example, rather than being subject to trends and external influences we claim that through the development of the Metro and other related infrastructure projects actors have supported the following trends: the changing character of cities from sub-national units to regional (European level) actors; the changing role of city government from planning responsible to relevant actors in a large-project market environment; the changing nature of infrastructure investment which is geared towards the consolidation of Europe rather than individual countries; the changing role of companies in infrastructure projects, where it is observable that the new temporal alliances occur among European firms, and not only Danish firms like in the past.

This analysis is based on historical material from the city of Copenhagen, the Metro Company and the involved ministries and administrative bodies. The authors conducted ten semi-structured interviews with experts working in the different units involved, including the head of the Metro project during the 1990s, former city engineers, city officials in key positions and ministry delegates.

The main findings of this research are that the Metro of Copenhagen is an intervention at the city, national and regional level staged by the governments of Copenhagen and Denmark in a joint effort. The Metro is not only a technological innovation in the sense that it is a fully automatic train system. The Metro is an innovation in the social and urban sense, because it is a key element in the process of changing the direction of development of Copenhagen as an urban unit. The Metro is one of the main pieces of an agreed strategy geared to realize a shared vision to support the re-generation and further development of the central areas of Copenhagen to enhance its competitiveness as a regional pole in the north of Europe. Therefore, the Metro plays also a role in the economic innovation of making Copenhagen the locomotive of Denmark, rather than its burden. Therefore from a theoretical point of view we can claim that rather than being passive subjects of external influences, the actors involved in the conception, development and materialization of the Metro actively participated in co-creating the socio-economical phenomena (influences), which the MLP relegates only to the landscape level. This also means that the Metro of Copenhagen is not a niche initiative that became part of the regime thanks to strategic protection and a timely window of opportunity. We claim, rather, that the Metro was a deliberate action of a constellation of actors to produce a significant change in the path development of Copenhagen as a city in Europe. In other words, it is difficult and misleading to classify the actions of the actors that developed the Metro interventions at niche, regime and/or landscape levels. An arenas of development approach is better suited to explain this process.

Arenas of Development

An arena of development is a socio-material space defined by a concern and populated by actors that engage and take action about it. The arenas concept draws on the actor network's relational approach to identify properties (meaning and qualities). The actors in the arena are diverse according to their natures and range from particular individuals to collectives of humans and non-humans to institutions. What defines the actors' relevance for an arena is their performance on and capacity to engage in this specific arena of development. As the arenas concept is not defined by scale or size and is used as a device to map and comprehend a given space of action the researcher does play an important part in choosing the arena used as the starting point for the analysis. Though the actors involved in a arena all are engaged not only in performing their (eventual transformative) actions within the arena, but they are also engaged in maintaining or restructuring the boundaries of the arena. Following this, the shaping of the arena is not simply a means of the researchers choice, but is the result of performed actions. There can be multiple arenas that overlap giving actors the possibility of multiple engagements that can either co-exist and be complementary or can be part of conflicts over the boundary of an arena. Arenas are also multiple (Mol, 2002). They cannot be objectively mapped. Mappings depend on actors' diverse natures and knowledge capacities.

To be able to account for the dynamics in a given arena or set of arenas, analysts can only follow the actions of certain actants, because "actors develop navigational strategies for transitions by establishing visions for societal change, engaging in technological innovation and changes in institutional frameworks, advising new patterns of use practices, and engaging in micro-political actions targeted at all levels, including changes in values, regulatory frameworks, and market configurations"(Jørgensen, 2012). Therefore any account is always temporal and must take the outset in actor's partial vision and actions. The quality of an arena of development analysis is dependent of the researchers ability to work out not only the central actors and their actor worlds (partial, eventually confined knowledge frames), but also the actions at the fringes of the arenas that stabilize or change the boundaries and thereby the stability of the arena.

In this analysis we choose to analyse the arena of development of mobility in Copenhagen at the time the Metro of Copenhagen is conceived, developed, constructed and entered into operation (phases 1 to 3). Currently the 4th phase of the Metro, the city ring, is under construction. The arena of mobility is then defined by the following concern: how should people move in Copenhagen on a daily basis for purposes of work, education, leisure and household maintenance? This concern brings into focus immediately the aspect of what is space in the city. In the following section we explore the implications of this aspect and then dive into the specifics of the story of Copenhagen.

Mobility and cityscape

The space within which the city transport systems are developing is populated by a number of very different actors and technologies. Through specific and situated historic process the heterogeneous socio-material structures - maps, institutions and means of transport - emergeas what at first sight might seem coherent. However,transportation systemsare plagued with inconsistencies, conflicts and instabilities. A city transport system is composed of several means of transport that are operated by institutional operators of trams, busses, metros, trainsand by individual drivers of cars, bicycles and trucks. Some of them have dedicated infrastructures (rails, stations) and others use and share parts of a common system of streets, bridges, tunnels and parking facilities. All in all this what constitutes the transport infrastructure. All involved actors, public and private, are created, grow or de-grow in a historically established cityscape. The institutions in charge of these systems perform their transformative actions both in everyday practices as in strategic planning and attempts to restructure through visions and material actions. Especially when they attempt large changes, they not only discuss the changes of a particular system, but they mess up with the construction of the cityscape and its social and economic foundations.

When approaching the field of mobility in cities several conceptions of arenas are offering themselves as possible entrance points to the analysis. One is the different types or means of transportation that are developed in relation to possible needs of cities, but also are operated by companies and co-operative structures across and outside the individual city. Even though historically speaking new means of transportation had local origins and for a time were locally developed and produced the contemporary renewal of transport systems is a transnational operation though still often dependent of specific locals when new models and systems are innovated. This is the case of the Copenhagen Metro that was designed and constructed by a temporary alliance led by the Italian firm Ansaldo-Breda in cooperation with several local engineering, infrastructure and architectural firms.

In this article our focus is on the Copenhagen Metro as a core element in the attempt of developing sustainable mobility in Copenhagen. But as a means of transport the Metro is not the single solution or not even the only important element to achieving this goal. Its success is dependent of a number of other measures linking together a larger system of transportation and making operational a multi-modal transport system not least dependent of changes in the everyday mobility practices of the Copenhagen population. In this respect the Metro itself become an actor in the mobility strategy to which the planners have attempted to delegate agency (Munch & Jørgensen, 2001).

The arena in question for this analysis is consequently not the arena for Metro development and operations neither at the industrial, cross national level, nor at the Copenhagen level, though the specific institutions involved in making decisions and providing the large scale investments are a crucial to the realisation of this specific and contemporarily important element of Copenhagen's transformation. The core arena involved in this case is the large arena of development for Copenhagen's mobility at large that include the other means of collective transportation and the partly co-operating, partly fundamentally competing individual means of transport dominated by private cars. This leaves aside the important means of transport related to goods distribution, services and rescue activities that as well are crucial to the development of a sustainable mobility system and operates on the same street infrastructure as the private cars, but still develops within a separate, overlapping arena.

One of the core controversies that has shown very important in several phases of the history of Copenhagen's transport system and consequently for the mobility arena is the role of road and highway planning that has serviced the inter-city connections in competition with another arena of the national railway systems. One could be tempted to define this other arena as a larger one, because it is a larger infrastructure. However, what defines an arena is a concern. In the case of the highway development, this has been mainly a concern at the national level to provide efficient mobility between cities. So it is by nature that this arena is different than the arena of mobility in Copenhagen. The two arenas however have interacted, when "highways began to enter into cities". In the case of the Metro of Copenhagen, as we will see, the two arenas interacted complementing each other. That is, Ørestad and the Metro of Copenhagen became parts of a national strategy to improve mobility also to and from Copenhagen towards the rest of the country, and specially, to the airport and to Sweden through the bridge to Malmø.

Metro's conception

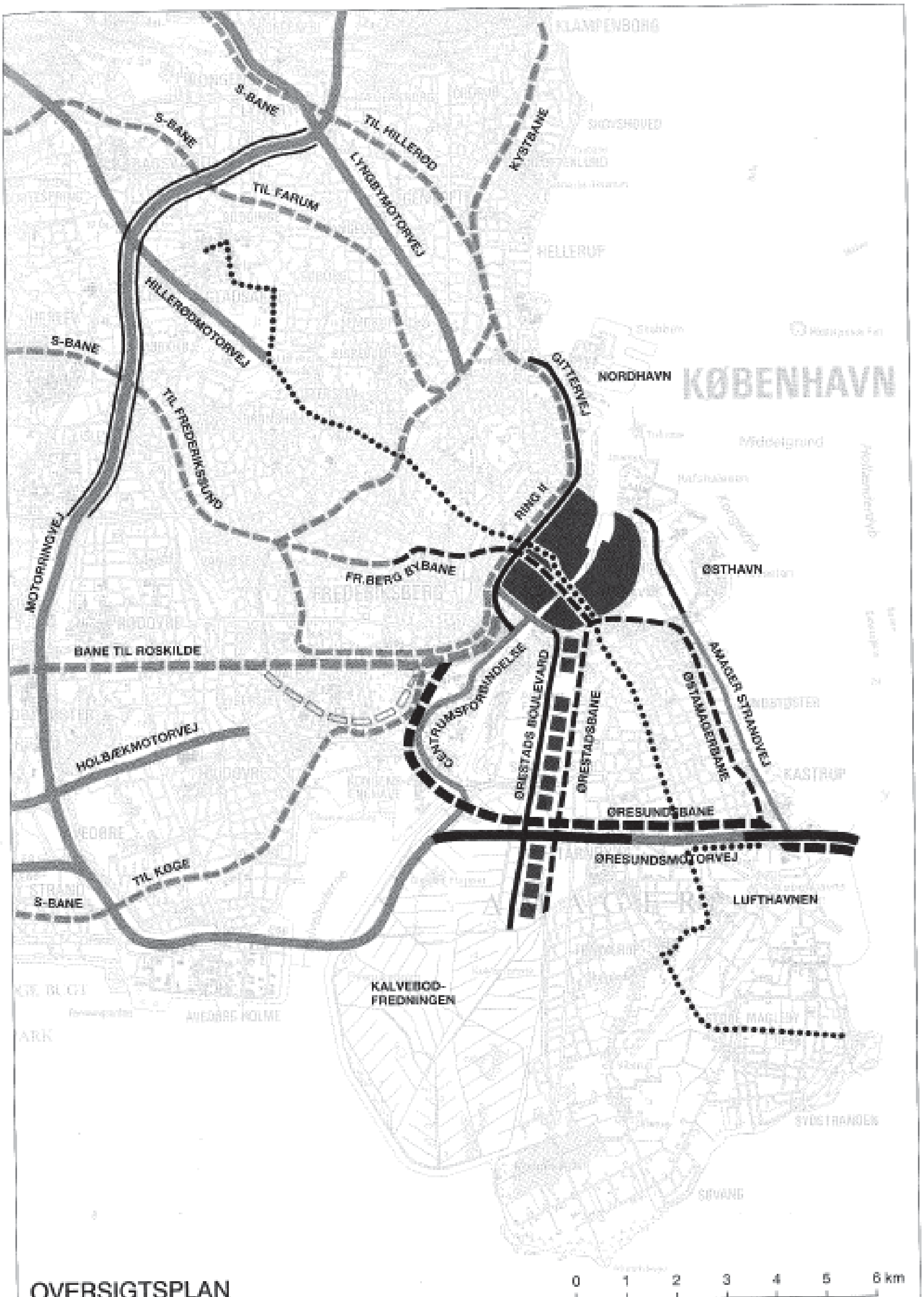
The Metro of Copenhagen was conceived by the members of a committee of experts and politicians appointed by the governments of Denmark and Copenhagen to find ways of structuring the development of the capital of the country. In a document called "Hovedstaden: hvad vil vi med den?" published in 1989, this committee outlined the main aspects of a concerted strategy to revitalize the development of Copenhagen (Metropolitan Commission, 1989). The way in which this document was written, reveals that the authors were worried about the decline of the city in terms of living conditions, transportation infrastructure and job opportunities. They also recognized that the nature of economic activities was changing with traditional industrial jobs declining in the country as whole and new service based jobs on the rise. They proposed that planning activities were also changing in nature, from state push to entrepreneurial pull. And finally they also proposed that future developments could not be financed by a city with economic difficulties, but by selling state properties.

Already in this broad political statement, the authors suggested the construction of a "Tunnelbane-projekt (Frederiksberg - Nørreport – Amager)" (Metropolitan Commission, 1989). Additionally they also suggested the construction of a bridge to connect Copenhagen with Malmø both by train and by car. These are the two most salient aspects of their propositions to affect the arena of development of personal transportation in the capital region and also affecting the arenas of national and international transportation both by car and by train.

They also proposed the redevelopment of Copenhagen's central areas, and the development of old port areas and the construction of a new town in the west unpopulated areas of Amager, very close to the city centre. These were the most important aspects suggested in this document which in several ways started a process of restructuring the boundaries of several arenas that so far had been rather independent of each other and primarily defined and related to different institutions, ownership structures and matters of concern. The Copenhagen mobility planning had been in focus one decade earlier with the establishment of a Greater Copenhagen Council, but the different interests of the involved municipalities had not lead to any important new developments besides the creation of a Metropolitan Bus Company that at the same time represented a privatisation of several former municipality driven bus companies. By bridging the arena of land use in the capital region and linking mobility to another development plan, that was stalled in the late 1960s the boundaries and thereby the focus on the arena of mobility in Copenhagen was starting to change.

The loose ideas proposed in the previous document were further developed in 1990 thanks to the government of Denmark's and Copenhagen's continued to support the process of revitalising the capital area with strong investments in transportation, particularly in public transportation infrastructure. A committee of experts was appointed to develop a technically and economically grounded proposition for the investments. Among the members of this committee were renowned civil servants, including Copenhagen's city engineer Jens Rørbech, and Anne Grethe Foss from the planning department of DSB. Representatives for the ministries of finance, energy, transport, environment and interior were also present along with those of the municipalities involved (Copenhagen and Fredericia). This committee, which became known as the Würtzen Committee, produced an assembled assessment of the situation of the capital region and a number of ideas of how to further develop the city in the future, from the point of view of investments in traffic (Denmark. Udvalget om hovedstadsområdets trafikinvesteringer, 1991).

The analysis first concentrated in assessing Copenhagen's competitive possibilities in the context of European city poles. This step signals the first major break with past developments. The Greater Copenhagen Area from this point onwards, is not seen as a major urban unit within Denmark and assessed against other cities in the country. This new assessment positions Copenhagen in relation to other cities or urban units in Europe like Stockholm, Oslo, Hamburg, the Randstad and Berlin. The underlying assumption in this analysis is as to what are the strengths of different cities in terms of communication, economy, research and technology and culture *in order to attract* future investments from private industries that create high profile service jobs.



OVERSIGTSPLAN
De i konklusionen omtalte trafikanlæg er vist med sort

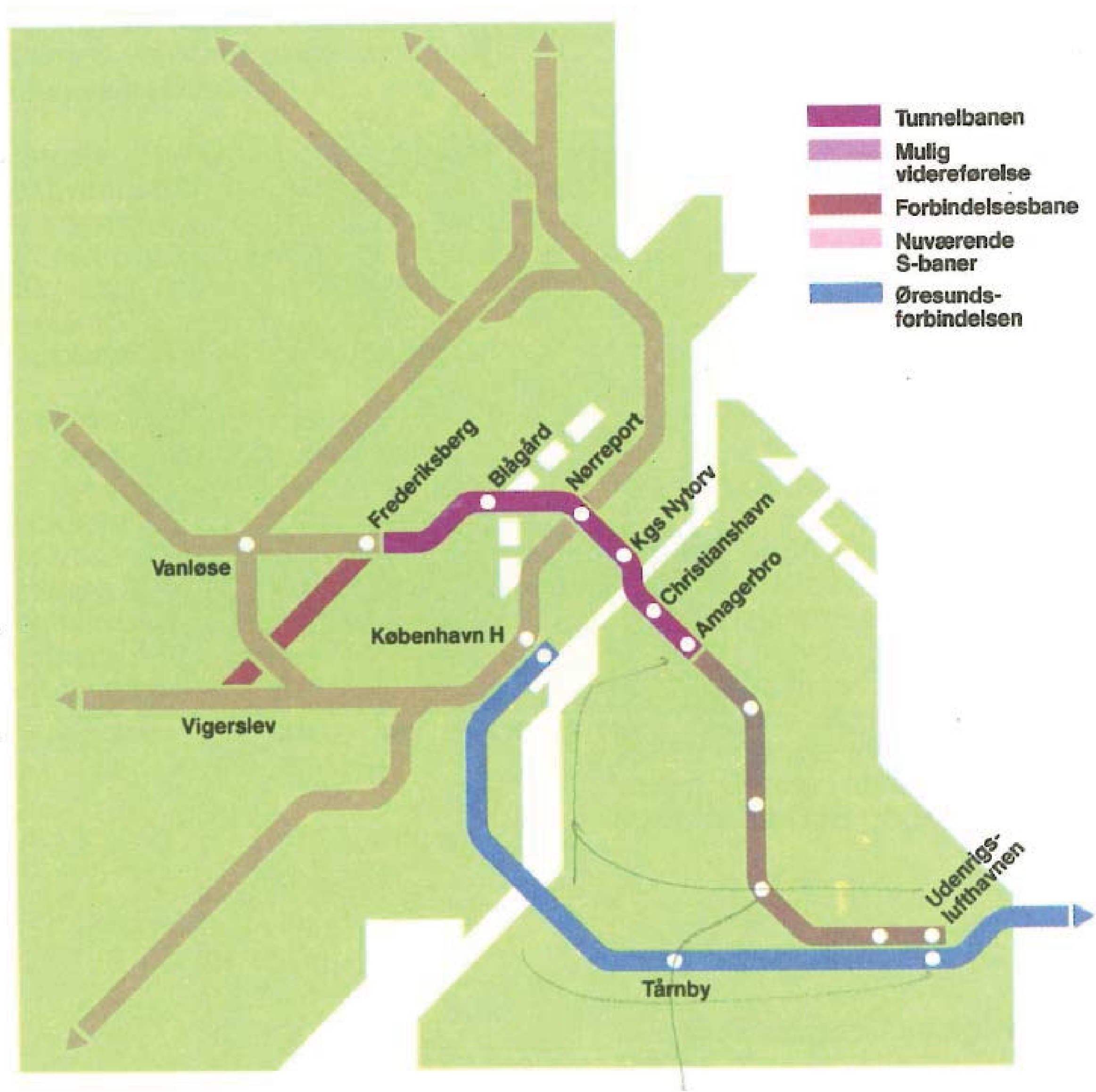
The proposal became an integrated set of investments to enhance Copenhagen's connectivity to the subnational and supranational regions including: the extension of the bridge over the Sound with regional and international trains through the airport to the central station of Copenhagen. Upgrading and completing the net of motorways around Copenhagen to improve car mobility and car connections between Denmark and Sweden without impacting the inner structure of the city (car traffic around the city). Upgrading the airport. Upgrading and improving the existing suburban train network (S-trains). And constructing a new train connection between the west areas of the city (Frederiksberg), the city centre (CBD) and two regions in Amager. The west areas were the new town of Ørestad was to be built. And the east areas were new redevelopments were considered possible in previously industrial neighbourhoods, with a connection to the airport (see diagram previous page).

The key economical proposal of this committee was to finance all the new investments (especially the new train connection), by selling the land of Ørestad, which was owned by the state (almost half and half by the national state and the city of Copenhagen). This is the single most important aspect that distinguishes the new investments from previous investments. Before this project almost all major investments were taken up by the state in Denmark on the grounds of national strategic planning and technically assessed needs. From then on, the state assumes the role of interest part and provides private companies with the responsibility of developing (planning, constructing and operating). And thus, the financing mechanism also changes. One difference in Denmark is that the state (national and municipal) can also own companies. And in this case, the many companies in charge of coordinating investment, construction and operation like Ørestadsselskabet, Metroselskabet, By og Havn and others, are owned by the state, but operate like a private companies.

The circle line of Copenhagen was also envisioned early in the 1990s as an extension of the planned connections between Frederiksberg, the centre of Copenhagen and Amager (Ørestad, Airport). It can be said that it literally grew out of the model thought for the initial investments. The circle line was however to be entirely underground and to serve mostly areas already populated. However the financing mechanism was thought to be the same. Selling land in the harbours for redevelopment projects would provided the funding necessary for the development and construction of the circle line. With this, the governments of Copenhagen and Denmark want to provide the capital city, and especially the CBD with a "mass rapid transportation system that will ensure Copenhagen citizens' mobility within the city throughout the 21st century" (Andersen & Jørgensen, 1995).

One could have thought that the projects of Ørestad, the Metro and its supporting pieces (highways, bridges) was part of a larger vision for Copenhagen, but it was not. The Regional Plan of 1989 that was developed by professional planners did propose a central growth scheme, but its main proposals were different in nature. The 1989 plan was a response to the 1973 plan that attempted to spread out the city towards the west and abandon the CBD. In short terms, the 1989 plan retakes the spirit of the 1947 finger plan to develop the city along the main suburban train corridors. There are two main differences: one, is that they propose the continued development of sub-centres among the fingers. In other words, this is not a mono-centric plan anymore. And second, attempting to create a balance in terms of number of jobs and residences in different areas in order to reduce one direction commuting at peak hours and in order also to limit expansion(Andersen & Jørgensen, 1995).

In the Plan 2000 outlined by DSB in 1989 they proposed also a solution to connect the city centre to the airport. However, by thinking within the technological framework of the company, the plan was to build an underground connection through the populated areas of Amager (see figure below). It is worth noting that this idea came from the same unit, the Planning Department, were the Metro was conceived. Other ideas competing within DSB included developing the large areas of rails adjacent to the main train station in Copenhagen to the south. The idea was to cover all those tracks making and constructing high-rise buildings on top.



Conclusion

If we were to tell the story of the Metro of Copenhagen from an MLP point of view, we would first have to define what is the regime in our case and this immediately poses a lot of problems. In many other MLP studies focusing on sectors or even cities, there has been a tendency to define the regime around a technology (Geels, 2005; Geels, 2007b). Although MLP studies have insisted that what defines a regime is a set of rules (Geels, 2007a) or routines (Geels&Schot, 2007). The idea of regime has been criticised for being overtly monolithic and for taking stability for granted (Jørgensen, 2012). In our case the regime is very difficult to pin down to a set of rules or routines as many "mobilists" in Copenhagen use different modes of transport according to their changing activities. Additionally, by the time the Metro was conceived and all the way through the construction and operation of the first 3 phases, what we constantly see is conflict and debate about performances, further investments and future developments. That is, we observe the opposite of stability in our object of study. Additionally, the mobility system in Copenhagen can hardly constitute a selection environment when decisions of investment are taken at a different level.

We would have to analyse in which respects the Metro was a niche and in competition with which other niches it was conceived and structured; we would also have to describe the dynamics of protection of this niche both internally (nurturing) and in relation to external actors (shielding and empowerment); we would also have to characterize the regime of transportation of Copenhagen previous to the conception of the Metro and how it changed as the Metro was developed, constructed and it entered into operation. Finally we would have to account for the landscape developments that supported the becoming of the Metro and that put pressure on the selection environment (the regime) to make this particular niche succeed.

Considering the above analytical choices would have put a straight jacket in our empirical material. What we see in the actions of the persons, the institutions and the non-human actors involved can only be characterized in MLP terms as a deliberate intervention at the three levels (niche, regime and landscape). In fact the promoters of the Metro and even those who opposed the project were not discussing only a transportation technology, but what was the human, geographical and economic foundation of Copenhagen's future development. In that sense, they were intervening at the level of the design of the system (niche), the configuration of the city's general transportation system (regime) and the rationale for those decisions (landscape developments).

The most salient aspect of the MLP, which cannot be applied, in this case is to consider the regime as a selection environment. In this case, the Metro did not compete with other alternatives. One reason is that market laws do not govern urban transportation technologies, because their use is heavily dependent on geographical configurations. Another reason is that thedevelopment of these systems requires heavy investments, and thus the involvement of powerful actors (states, city governments) that have the capacity to configure the regime as a whole with either projects or regulations or combinations of both. Furthermore, these powerful actors are not necessarily committed to preserve the regime, but on the contrary might be committed to influence its development in a different way. In short, the current configuration of a regime might be a burden to get rid of, instead of a value to preserve.

Another aspect of the MLP that also does not apply in this case is the nature of the protection granted to a niche to succeed in the selection environment. Smith and Raven(Smith & Raven, 2012) distinguish between shielding, nurturing and empowerment as passive ways of protecting a niche. These are passive because niche actors do not influence them. Shielding can be achieved by protective regulations to new technologies; nurturing by ad hoc allocation of resources; and empowerment by supporting activities for the niche and active disempowerment of other actors in the regime. But in our case what we observe is that the same actors that supported the development of the Metro are also responsible for the development of the other technologies that constitute the transportation system of the city. So, again, there cannot be observed a dynamic of protecting the niche to succeed in the selection environment, but a whole strategy to affect the development of the regime through a strategically designed project.

In terms of landscape it is tempting to say that neoliberalism as an economical dogma, new public management as administration paradigm, the expansion of the European Union, automation as an inevitable technological trend, the re-birth of cities and specially city centres in Europe are all external influences that affect the development of the Metro of Copenhagen. However, what we see through our empirical material is that these influences were brought into the process at different times to structure narrative, support decisions and define criteria. Furthermore we observe in many cases the same Metro project contributed to configure and strengthen the influence. Particularly the support to public transportation projects to make cities greener and thus more attractive to investment has been an international trend heavily constructed on the case of Copenhagen.

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Role of demonstration projects in innovation: transition to sustainable energy and transport

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Introduction

Transition towards more sustainability has been on the agenda of politicians, researchers, industry and concerned societal actors for a number of years. The oil crisis in the 1970s, environmental concerns related to decreasing biodiversity, depleted natural resources, cities polluted by emissions from road transport, and climate changes caused by greenhouse gas emissions, all these crises have contributed to a sense of urgency in political statements on the need for transition towards a sustainable society. Politicians have developed different types of instruments to achieve a development towards more sustainability. However, the design and proper mix of such instruments is still to be better developed, as is the knowledge on possible effects of these instruments. This applies also on demonstration projects and programmes.

This paper attempts to review two important strands on literature relevant for our understanding of demonstration projects and trials for the transition towards more sustainability: Firstly, the literature on demonstration projects and trials, applying rather different conceptual frameworks, among others technological innovation systems, and secondly, the broad literature on socio-technical systems and strategic niche management. The analysis of the first shows a focus on technological solutions and to a much lesser degree a focus on institutional embeddedness and societal changes induced by such projects. To prevent such one-sided shift of focus we conclude our review with a short but to our mind relevant account of transition theory.

Our literature review is guided by the research questions for the InnoDemo project:

1. What are the main contributions of Scandinavian demonstration and trial projects and programmes to sustainable energy and transport transitions?
2. How should the governance of such projects and programmes be developed to further support their contribution?

Therefore, we look both at possible outcomes of such projects and at the organisation and governance of the programmes supporting such projects. This paper will serve as a conceptual guidance for compiling a comprehensive database over all relevant demonstration projects and programmes in the three Scandinavian countries, a survey of the identified projects and programmes and interviews with involved stakeholders.

Demonstrations as policy instruments for facilitating learning processes and diffusion of new technologies

The following overview will give a summarizing account of the literature which is addressing specifically demonstration projects as a policy instrument for technology innovation. We distinguish here between two periods: (1) literature about the experiences of US-demonstration projects and programmes in general in the 1970s, 1980s and 1990s (Clark & Guy, 1998; Macey & Brown, 1990; Magill & Rogers, 1981), and (2) literature about demonstration projects for energy technologies, such as wind power, solar photovoltaic energy and fuel cell technology, covering Europe, the US and Japan (J. Brown & Hendry, 2009; Harborne & Hendry, 2009; Harborne, Hendry, & Brown, 2007;

Hellsmark, 2011; Hendry & Harborne, 2011; Hendry, Harborne, & Brown, 2010; Lefevre, 1984; Sagar & Gallagher, 2004).

Experiences of US-demonstration projects and programmes in the 1970s, 1980s and 1990s

The US experiences with demonstration projects and programmes refer to federal activities for a broad range of technologies, from agriculture, to education, housing, environmental protection, health, transportation and energy (Baers, Johnson, & Merrow, 1977; Macey & Brown, 1990). According to Magill & Rogers (1981), the US Department of Agriculture supported for over 70 years "demonstrations in diffusing agricultural innovations" (1981:24). Both Magill & Rogers (1981) and Macey & Brown (1990) give reference to work of Baer et al. (1977) and Myers' report on the role of demonstration projects for accelerating the application of new technology (Myers, 1978).

Baers et al. analyse 24 demonstration projects funded by 11 different federal agencies and they state that "a demonstration focuses on market demand, institutional impact, and other non-technological factors, the goal being to provide the basis for well-informed decisions on whether to adopt the technology" (1977:950). Baer et al. distinguish between field trials to prove a technology and demonstrations, and they reduce demonstrations to a test for the market. They emphasise market failure as the main rationale for government support of demonstration projects. Baer et al. (1977) emphasise following attributes for diffusion success: a strong industrial system for commercialisation, low technological uncertainty, and no tight time constraints.

Myers (1978), however, argues that it is necessary to distinguish between two types of demonstration projects: (1) *experimental projects* for "testing the workability of an innovation under operational conditions", and (2) *exemplary projects* "to demonstrate the utility of the innovation to potential adopters (that is, to diffuse the innovation)" (summarised by Magill & Rogers, 1981:27). Magill & Rogers emphasise that by mixing these two types of demonstration projects in prior research it was difficult to determine whether or not a demonstration project can be assessed as successful or not. Projects which are more experimental can by definition not contribute to the diffusion of the technology, but they can have contributed quite successfully to the testing of the technology under operational conditions. According to Magill & Rogers (1981:28), Myers (1978:15) highlighted that these two types of projects differ regarding to audience, design and attitudes of demonstration managers.

Clark and Guy (1998) understand demonstration projects as examples "where public funding is used to sponsor preparation of a facility showing the capabilities of a technology, and its subsequent demonstration to potential users" (1998:387). They refer as well to the study of Baer at al. (1977) and they too do not distinguish between experimental demonstrations and exemplary demonstrations.

Boyd, Borrison and Morris (1983) analyse determinants for success of demonstration projects[1]. They distinguish between three dimensions of success: application success, information success and

[1] This paragraph is informed by the information given in the article of Macey & Brown (1990).

diffusion success, and single out different conditions relevant for the success. The conditions which lead to these dimensions of success are summarised in the following table. Boyd et al. point out that a new technology has different market values in the early high-value market and in the mature market which include lower-value applications. However, they do not mention the importance of market niches at early stages. For them it is essential to assess how the new technology fits into the existing mix of technologies, that means the existing socio-technical regime, and not how it could overcome this mix.

Table 1: Determinants of successful demonstration projects (adapted from Macey & Brown, 1990, and Boyd et al., 1983)

Attribute of demonstration project	Application success	Information success	Diffusion success
Technology “well in hand”	X	X	X
Well-designed experiment focussed on precise objectives	X	X	X
Significant initiative for demonstration from potential users	X	X	X
Significant cost sharing by participants	X	X	X
Significant risk sharing by participants	X	X	X
Demonstration applicable to variety of sites		X	X
All key parties are involved		X	X
Well-defined high potential initial market			X
Conclusive to decision making on economic basis, minimal impediments			X
Supply and support industry in place			X

Macey & Brown (1990) keep the distinction between the two types of demonstration projects – experimental and exemplary projects, but they distinguish also between *two phases of exemplary demonstration projects*. In the *phase 1 projects* the main goal is “to communicate information and promote the technology primary to opinion leaders and early adopters”, while the main goal in *phase 2 projects* is “to reach the broader range of adopters…: it may be periodically adjusted or adapted to meet differing local demands as its application environment extends” (1990:230). Macey & Brown underline that the success of an exemplary demonstration should not necessarily be measured by the adoption of the technology, but by analysing if the project influenced planning and implementation decisions (1990:229). The three different types of demonstration projects have different roles in the innovation process and their success or failure has to be assessed differently. Macey & Brown highlight following reasons for success or failure of demonstration projects: (1) user involvement is crucial at all stages of demonstration projects to facilitate information and learning, (2) project design should not be rigid to allow user input and modifications to improve effectiveness, (3) careful planning to take account of market readiness and user participation, (4) dissemination of results and evaluation information should be included in the project design (1990:234).

Government support for demonstration projects can "influence the diffusion of innovations indirectly by indicating to potential adopters the direction of federal policies and priorities" (Macey & Brown, 1990:231). In terms of functions of technological innovation systems this can be captured with the concept "guidance of the search", one of the main functions of technological innovation systems (i.e. Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008; Hekkert, Suurs, Negro, Kuhlmann, & Smits, 2007).

Demonstration projects for energy technologies

Lefevre defines demonstration programmes as attempts "to shorten the time within which a specific technology makes its way from development and prototype to widespread availability and adoption by industrial and commercial users" (1984:483). Lefevre shows that the complexity of demonstration projects is caused by two reasons: Firstly, demonstration projects have to serve different objectives, beside technological issues a "variety of economic and environmental considerations" (484) have to be addressed. He lists as non-technical objectives of demonstration projects stimulation of new industries, further training of installers and maintenance personnel, public acceptance and involvement of existent industrial manufacturers (485). Secondly, demonstration projects have to develop a division of administrative responsibilities between governmental or other public agencies and private participants and conflicting interests have to be addressed and settled. Conflicting interests may occur regarding the dissemination of the results of the demonstration because the private partners have an interest to treat the results as proprietary. Lefevre points out that it is necessary to discuss when it is proper to select demonstration projects as a proper policy tool to accomplish political and technological goals. He highlights following issues as relevant:

1. *Allowance for failure:* demonstration projects are experiments and should include the possibility to shift back to technical verification in the case of evidence for technical prematurity;
2. *Cost and risk acceptance:* if the private sector is willing to accept costs and risks this is an indication for near-term or medium-term commercialisation;
3. *Trialability:* prospective adopters can sample the innovation; in the case of modular innovations this may be easier;
4. *Audience identification:* should distinguish between technical (engineers, architects, planners etc.) and non-technical audience (residents, general public);
5. *Audience predisposition toward innovation:* is the intended audience favourable of the innovation or do they have to change their behaviour;
6. *Need for inducements beyond demonstration:* the future commercial success of a demonstrated innovation may depend on other public policy instruments, such as "purchase commitments,

> tax exemptions and credits, and other incentives for manufacturers and buyers" (Lefevre, 1984:489).

Sagar and Gallagher (2004) give an account of primarily US activities in energy technology demonstration and deployment. Regarding demonstration projects they highlight three roles of such projects helping the demonstrated technologies closer to the market: (1) test a new technology in real-world conditions and gathering technical and economic performance data that can help refine the technology; (2) help in scaling up a technology which is important for technologies which require much larger scale for testing than usual laboratory tests; and (3) demonstrate the feasibility of the technology for the market and therefore enhance their confidence (2004:3). Sagar and Gallagher provide also a review of prominent energy technology demonstration and deployment *programmes*. However, regarding the assessment of demonstration programmes they concentrate on the government budgets for such programmes. In 2006, Gallagher et al. repeat the same argument that demonstration projects "bring technologies closer to the market" in three ways: (1) testing new technologies under almost real-world conditions, including the collection of technical and economic performance data to refine the technology, (2) scaling-up technologies from the laboratory test stage, and (3) demonstrate feasibility under real-world conditions to manufacturers an potential buyers (Gallagher, Holdren, & Sagar, 2006:203).

Aims of demonstration projects and trials

Harborne and Hendry define demonstrations and trials as

> "a government-funded programme or project that has specific technological, operational, and social objectives; with an overall budget and duration; which invites bids with a clear specification of goals; evaluates projects against these, requires a formal management structure; and provides ongoing customer/user support from the manufacturer or operator" (Harborne & Hendry, 2009:3586).

While the MLP stresses the importance of experimentation for sustainability transitions, surprisingly few studies have explicitly focused on and theorized the role of demonstration projects, with the exception of the group around Harborne, Hendry and Brown (Harborne & Hendry, 2009; Harborne, et al., 2007). This group investigates especially the role of demonstration projects for transitions to a low-carbon energy sector, and here especially for complex large-system innovations. Also they highlight combatting 'market failure' as the main rationale of public demonstration interventions, covering "national security, economic opportunities and societal benefits", including mitigating climate change (Hendry, et al., 2010:4507). They understand demonstration projects as an "extension of the prototyping process" to overcome uncertainties. These uncertainties, however, include not just technological or market uncertainties.

The group around Harborne, Hendry and Brown has developed a taxonomy for demonstration and trial projects and programmes according to their *aims* (Harborne & Hendry, 2009:3588; Hendry, et al., 2010):

1. prove technical feasibility,
2. reduce building, materials, components, operating and maintenance costs,
3. prove feasibility in commercial applications, and
4. hybrid projects.

We suggest adding three further categories, (5) prove environmental feasibility, (6) develop public awareness and acceptance, and (7) introduce institutional embedding for societal change. In practice most of the projects and programmes have multiple aims. Therefore the category 'hybrid' will probably dominate.

Hellsmark (2011) applies in his thesis the technological innovation system approach with the focus on the different functions of such systems (Bergek, Hekkert, & Jacobsson, 2008; Bergek, Jacobsson, et al., 2008; Hekkert, et al., 2007) in his analysis of the role of system builders in realising the potential of second-generation transportation fuels from biomass. Following Karlström and Sandén (2004) he identifies demonstration projects as "a particular type of materialisation that is important in the industrialisation of new knowledge fields" (Hellsmark, 2011:34). The function of materialisation has not been so much explored in analyses of technological innovation systems, but this concept captures "the process of strengthening the development and investment in artefacts such as products, production plants and physical infrastructure" (Hellsmark, 2011:33) and in this respect this concept builds on large technical systems of Hughes (Hughes, 1987; Joerges, 1988).

Hellsmark identifies following roles of demonstration projects related to the different functions of technological innovation systems: (1) they contribute to the formation of knowledge networks, (2) they reduce technical uncertainties, (3) they facilitate learning that can be instrumental for decisions on technology choice, (4) "they may also raise public awareness of the technology, strengthen its legitimacy and expose system weaknesses such as various institutional barriers" (2011:34), and, (5) they may form a starting point for advocacy coalitions. Karlström and Sandén list three types of results of demonstration projects: (1) learning which will be fed back into technical development, (2) open up a market by improved public awareness and scrutinizing institutional barriers, and (3) developing a network of actors (2004:288).

Organisational solutions

The group analyses different *organisational solutions* for demonstration and trial projects and programmes (Hendry, et al., 2010:4508f.). They identify following organisational solutions:

1. one-off high profile 'demonstrations 'and competitions to create public awareness about the potentials of a new technology at an early stage;
2. coordinated 'programmatic demonstrations 'to systematically measure, test, evaluate and characterise technology for a particular application, often comparing different models and technologies;

3. programmatic ‘field trials’ and tests to improve the performance and reduce costs, in the immediate run-up to commercial roll-out backed by subsidies and incentives, contributing to the development of installation know-how and the establishment of standards; and
4. permanent testing and demonstration facilities (‘test centres’), providing a learning facility and knowledge resource, and supporting manufacturers in many ways, including product certification.

While demonstration projects are considered crucial on a system level for the emergence and diffusion of radical new technology, it remains less clear why and how individual organisations engage with such form of experimentation. On the one hand they provide valuable stimuli to reduce the inherent uncertainty and risk associated with radical new technologies, while on the other they may help incumbents to innovate and/or imitate to prevent new technology to breakthrough (Harborne, et al., 2007). The group has a focus on manufacturers of renewable energy technology because the manufacturers have experience with technological innovation and participate in a large number of such projects.

> This focus “neglects the wider social process of getting ‘buy in’, on which successful innovation depends. While DTs have at times encouraged collaboration to overcome barriers, policy makers have not systematically built socio-political considerations into programmes. Equally, they were rarely mentioned by companies, although apparent to observers. It remains a neglected issue in designing and managing DTs” (Hendry, et al., 2010:4511).

That means that our study should address also the wider social process, not just the technical aims of the projects and programmes. This has percussions on which types of actors will be involved in the interviews and focus groups.

Regarding organisational solutions several themes have been discussed more thoroughly by Hendry et al. (2010): (1) the coordination between technical development and demonstrations and trials, (2) structured steps from technical development via demonstrations and trials to market development, (3) market development before technology advance, (4) learning effects and unintended benefits, and finally (5) capturing and spreading learning. The first two themes address two issues: firstly, problems related to firms’ attempts to use government subsidies for demonstration projects and trial for own R&D activities, which should be finance by them and not be government means. Secondly, the process from R&D via demonstrations and trials towards commercialisation is not a linear one. This means that demonstration projects and trials will naturally lead to loops back to R&D activities. These processes have to be considered and coordinated. The third theme addresses the maturity of the technology deployed – it is also evolving: we can distinguish between different generations of technology – while the first generation can already be commercialised on the market, a second or third generation undergoes refinements in R&D and demonstration and trial projects. And subsidies for demonstration projects and trials of new generations of technology should not be used for the older generation of technology. In the next section we cover mainly theme (4) and (5) related to learning.

Regarding the second theme Karlström and Sandén distinguish between demonstration projects in different phases of the formative period of a technology's life-cycle: In the *experimental phase* demonstration projects should "be designed to maximise learning and novelty" and a variety of projects should be selected. In the *take-off-phase*, where market growth is the aim, consumer awareness and network formation become important and therefore demonstration projects should support the prove of technological and financial feasibility, outreach activities and institutional embedding (Karlström & Sandén, 2004:288). This distinction is important when the timing of certain types of demonstration projects is to be considered. Another important feature to be considered is the size of a project (ibid). Some issues cannot be demonstrated on a small scale and require therefore large projects, especially demonstrations of system innovations fall in this category and require often full-scale demonstrations (see also the section on Large Technical Systems).

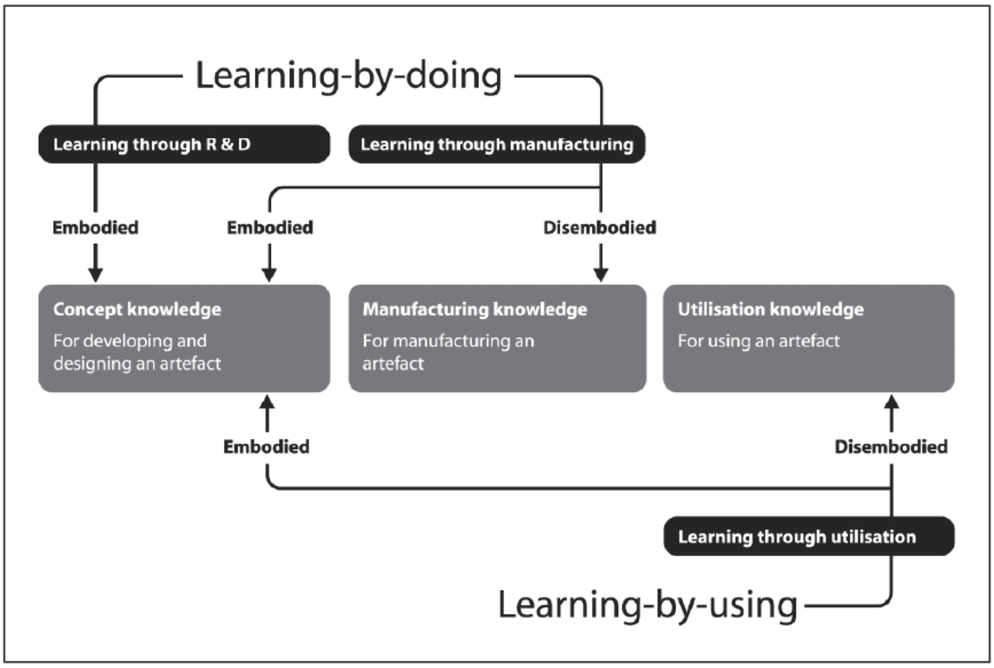
Learning outcomes of demonstration projects and trials

The group around Harborne has developed a database of "demonstration projects and field trials in the development of wind power, solar photovoltaics and fuel cells from the 1970s to the present day", interviewed key experts and performed case studies on a number of organisations (Hendry & Harborne, 2011:779; Hendry, et al., 2010). For wind power there are listed 148 programmes and projects at 577 sites in Europe, Japan and USA (ibid) and nine case studies, and for solar PV 92 programmes and projects and 15 case are studies listed (J. Brown & Hendry, 2009; Hendry, et al., 2010). The database allows them to analyse (1) the "impact of government strategies" on demonstration and trial programmes and their objectives, (2) "stakeholder involvement and location", (3) "evolution in design and technology supported by successive programmes", and (4) "stakeholder learning and the effects on manufacturing capability and competitiveness" (Harborne & Hendry, 2009:3587). Brown and Hendry (2009) apply also the concept "dominant design" when analysing the application of solar photovoltaic technology, distinguishing between a fluid phase with a number of competing solutions and the emergence of a dominant design for grid-connected PV and off-grid PV installations. The emergence of new generations of PV technologies will however contribute to a new "S-curve" (ibid.:2570).

Harborne and Hendry stress the importance of understanding the contribution of demonstration projects for learning processes and the coordination of policy measures in support for the development and deployment of new energy technologies (Harborne & Hendry, 2009:3581). Tax credits and other demand-pull instruments are not to be categorised as trials or demonstrations, but projects supported by such instruments can also include relevant learning and feedback possibilities. Hendry et al. (2010) highlight that demonstration and trial projects should ensure in their budgets performance monitoring, maintenance and trouble-shooting, which are all essential for learning. The group highlights the non-linearity of innovation trajectories and apply a "socio-technical systems approach" (Harborne & Hendry, 2009:3580) stressing the importance of different modes of learning in different phases of these systems (Hendry & Harborne, 2011).

We can distinguish between learning by *searching* (mainly R&D to acquire know-why in the form of formalised knowledge), learning by *doing* (mainly 'rules of thumb' and know-how acquired during manufacturing as tacit knowledge), learning by *using* (mainly know-how acquired in the utilisation of technology and especially important for complex, interdependent systems of products and acquired by the users of a technology), and learning by *interacting* (mainly necessary for complex innovations direct interaction between users and producers are necessary) (Kamp, Smits, & Andriesse, 2004).

Figure 1: A model for knowledge and learning (Dannemand Andersen, 2004: 41)



Elaborating further on these types of learning Dannemand Andersen (2004) distinguishes between different types of knowledge: *concept* knowledge, *process* knowledge and *utilisation* knowledge. However, Dannemand Andersen defines learning through R&D as learning by doing (Figure 1), while Kiss and Neij (2011) apply the above introduced the distinction between learning by searching and learning by doing as Kamp et al. (2004). Kiss and Neij highlight that learning by searching and interactive learning have been facilitated through governmental RD&D (2011: 6521). However, they point out that testing and technology certification has supported learning by doing and learning by interacting and they do not address demonstration projects or programmes. "Learning-by-interacting is based on actors' involvement, interaction and networking, as well as enhanced by mutual interest and change agents" (Kiss & Neij, 2011:6522). The concept of experiential learning has been discussed (Dannemand Andersen, 2004; Rosenberg, 1982) in relation to the type of learning taking place while project participants are collaborating on building new technological solutions and refining them as they are used and the importance of communication across functional boundaries for example between designers and producers (Vincenti, 1990).

The concepts developed by Lundvall and Johnson (Lundvall & Johnson, 1994) on the learning economy are not based on Agyris and Schön (1978), but draw upon on Ryle's (1949) concepts of know-how, know-what etc. These concepts have been developed into a theory of interactive learning which is relevant for all stages of the demonstration project. The further development of these concepts into the STI/DUI model (Jensen, Johnson, Lorenz, & Lundvall, 2007) is particularly relevant for understanding the combination of scientific knowledge and practical experience necessary for success in a demo project. Some other concepts of learning such as those developed by Lorenz and Lundvall (2011), which include certain aspects such as the freedom individuals have to take decisions and solve problems. This might be particularly relevant for understanding the particular learning processes taking place in a demonstration project.

However, we cannot find evidence for that the science, technology and innovation (STI) mode is dominating totally in demonstration projects and trials in comparison to the doing, using and interacting (DUI) mode (Jensen, et al., 2007). We assume that demonstrations and trials have elements of both modes of innovation: in such projects new technology has to be used to demonstrate their functioning both for the firms, potential customers, and concerned citizens. And we have interactive processes, since such projects mostly are practiced in an interactive setting, especially if they are institutionally embedded. The STI mode is also prevalent, since the assumptions of the demonstrated technology will be verified or modified due to the exposure to real-world-conditions in the experiments. Such results have to be codified in reports and manuals, standards have to be developed and eventually harmonised in cooperation.

In connection to knowledge and learning, the concept of the 'knowledge base' might contribute to a better understanding also of demonstration activities. Asheim and Coenen distinguish between two types of knowledge bases, a synthetic and an analytical knowledge base (2005:1176). A *synthetic* knowledge base conceptualises innovation processes dominated by "the application of existing knowledge or through new combinations of knowledge" (ibid), while an *analytical* knowledge base "refers to industrial settings, where scientific knowledge is highly important, and where knowledge creation is often based on cognitive and rational processes, or on formal models" (ibid). Drawing on the concept of knowledge bases, (Moodysson, Coenen, & Asheim, 2008) further refine the distinction for the analysis of innovation biographies. Here innovation is conceptualized as a learning process that involves 'analysis' and 'synthesis'. `Analysis' refers to the understanding and explanation of features of the (natural) world. `Synthesis' refers to the designing or construction of something in order to attain functional goals (Simon, 1969). Analysis typically belongs to the realm of natural science, whereas synthesis typically belongs to engineering. However, these concepts are more or less ideal types. In demonstration projects both knowledge bases often come together since demonstration projects tend to involve not just research collaboration between firms and research organisations, but also interactive learning with customers and suppliers (Asheim & Gertler, 2005). When adding a spatial dimension to the analysis of demonstration projects by introducing territorially embedded regional innovation networks, regionally networked innovation systems, and regionalised national innovation systems (2005:1179f.), this might become still more evident.

Harborne, Hendry and Brown (Harborne & Hendry, 2009; Harborne, et al., 2007) follow Karlström and Andersson in their distinction of different *results of demonstration projects* supported by the government: “(i) learning, (ii) opening a market through increasing customer awareness and clarifying institutional barriers, and (iii) forming a network of actors to drive technology and policy change” (Harborne, et al., 2007:169). They highlight that government policy has to take into account the impact of a range of competing technologies and therefore to consider multiple demonstration projects, not just to pick one winner. Their analysis of demonstration projects for fuel cell technology in public busses reveals that (1) these demonstration projects are purely framed as technological and not as social experiments which explains some of the limited results; (2) alternative technologies complicate a picking winner strategy and therefor they suggest building socio-technical scenarios to establish a social vision (2007).

Hendry et al. addressed an issue related to who has ownership of the learning outcomes of the demonstration projects and trials (2010:4516). How far the learning has been captured only by a single firm or has been disseminated to others remains a question. Different stakeholders have different interests and can act differently in the diffusion of the results of the projects. An issue is also how larger companies and SMEs collaborate in such projects and how the companies retain control of significant intellectual property. Hendry et al. concluded that it may be easier to enable learning “down the supply chain than in promoting technology exchange between partners” (2010:4517).

Multi-level perspective on socio-technical systems

Social scientists have reflected on the above mentioned crises and political agendas and they have developed different theoretical approaches to address the need for transition towards more sustainability. In general, these theories apply a systemic perspective on society. Transition is here understood as shifts or ‘system innovations’ between distinctive socio-technical configurations encompassing not only new technologies but also corresponding changes in markets, user practices, policy and cultural discourses as well as governing institutions (Geels, Hekkert, & Jacobsson, 2008). Geels and Schot (2010) characterize transitions as following: (1) co-evolution and multiple changes in socio-technical systems or configurations, (2) multi-actor interactions between social groups including firms, user groups, scientific communities, policy makers, social movements and special interest groups, (3) ‘radical’ change in terms of scope of change (not speed), (4) long-term processes over 40–50 year periods.

A group of Dutch researchers developed the multi-level perspective (MLP) on socio-technical systems which we have chosen as the main conceptual framework for studying the role of demonstration projects. The MLP distinguishes between three levels in a socio-technical system: (1) the socio-technical regime, (2) the socio-technical landscape, and (3) the level of niches (Raven, 2005:31f.).

These three levels form a kind of "nested hierarchy", a level of structuration they provide to local practices (Raven, 2005:32).

(1) Rip and Kemp define a technological regime as following:

> "A technological regime is the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems – all of them embedded in institutions and infrastructures" (Rip & Kemp, 1998:338).

Geels distinguishes between three kinds of rules: regulative, normative and cognitive rules. Regulative rules constrain behaviour and regulate interactions, such as laws, incentive structures, protocols and standards. Normative rules are for example values, norms and role expectations. Cognitive rules are for example priorities, problem agendas, beliefs and search heuristics of engineers (Geels, 2005:14). Geels develops the concept of technological regimes further and introduces the concept of a *socio-technical regime*. The purpose of this concept is to see that also other social groups incorporate rules beside the engineering community. Geels distinguishes between a user and market regime, a socio-cultural regime, a policy regime, a science regime and a technological regime – and all these regimes are centred on and aligned with a technological system or technological artefact and form the socio-technical regime (Geels, 2005:17).

Raven exemplifies this for the electricity regime as following: "the alignment between the rules upheld by users (e.g. their preferences regarding electricity supply), policy makers (e.g. regulations regarding emissions), engineers (e.g. design heuristics regarding power production), etc." (Raven, 2005:29).

Raven points out that a "socio-technical regime results in a socio-technical trajectory, the pattern that emerges from dominant practices in engineering, use, policy making, scientific research, etc." (Raven, 2005:29). This trajectory maintains the dominant regime, secures stability and makes it difficult for new actors to deviate from the proven and incorporated rules.

Hoogma et al. emphasize that most changes in the socio-technical regimes are non-radical: their purpose is the optimization of the regime and not a transformation of the regime; outsiders have an incentive "to develop innovations that can be easily integrated into existing processes and products" and "there are path dependencies that act to contain radically new technologies" (Hoogma, Kemp, Schot, & Truffer, 2002:20).

(2) The *socio-technical landscape* is characterised by deep structural trends and major events which are external to the development of the socio-technical regimes: "Natural resources, infrastructures (electricity, roads, city planning), political cultures and coalitions, lifestyles, macro-economic aspects (oil prices, recessions), demography, and so on are part of this wider context (Geels and Kemp, 2000:18)" (cited by Raven, 2005:31f.). The socio-technical landscape is not influenced directly by the success of local innovation processes, however if a number of regime-shifts succeed, this will also affect the landscape (Hoogma, et al., 2002:27).

(3) The *niche level* is the place were radical innovations which break with the dominant socio-technical regime can be protected and nurtured (Coenen, Benneworth, & Truffer, 2012). “Regime-shifts often start at the periphery of existing dominant technological regimes in small, isolated application domains” – they often first appear in niches (Hoogma, et al., 2002:22). Raven emphasises that niche-activities are characterised by uncertainty: “Actors have to invest time and effort into creating and maintaining structures from which they can derive knowledge or practices (e.g. platforms, participation in conferences, etc.)” (Raven, 2005:32). Hoogma et al. define niches as following:

> “special application domains that are protected from (some of the) rules in the regime, e.g. price/performance ratio, user preferences or regulatory requirements. Protection – for instance, subsidies or regulatory exemptions – from the technological regime can create a proto (temporary) market that provides a testing ground for novel technologies. A technological niche facilitates learning and improves societal embedding; technologies may improve or new functionalities may emerge. In SNM, technological niches are the breeding place for radical innovation.” (Hoogma, et al., 2002:9).

We can distinguish between technological niches and market niches: in market niches the selection criteria are different from the existing regime, while in technological niches “resources are provided by public subsidies or strategic company investments” (Geels & Raven, 2006:377).

Strategic Niche Management

The Strategic Niche Management (SNM) approach has been developed to address niche processes and to some degree to provide policymakers a tool for supporting niche development (Hoogma, et al., 2002:29). Kemp, Schot and Hoogma (1998:186) define Strategic Niche Management as:

> “the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of the new technology and (2) enhancing the further development and the rate of application of the new technology.”

Policy intervention in socio-technical systems is not only relevant for the selection of niche technologies through experimentation. Policy interventions also include “the articulation of expectations and visions, network formation, resource allocation, favouring open-ended learning processes, and supporting technology diffusion (up-scaling)” (Coenen & Díaz Lopez, 2010:1156).

According to Raven (2005) distinguishes Hoogma (2002:67) between four types of experiments relevant for creating niches: (1) *explorative experiments* at early stages of learning to help define problems, explore user preferences and possibilities for changing the innovation, and learn how future experiments should be set up; (2) *pilot experiments* to raise public and industrial awareness, stimulate debate and open policymaking, test the applicability of innovations in locations with similar conditions or to test the feasibility and acceptability of innovations in new environments; (3) *demonstration experiments* to “show potential adopters how they may benefit from the innovations. They may either be the follow-up of explorative or pilot experiments, or be designed specifically to promote the adoption of an innovation" (Raven, 2005:38); (4) *replication or dissemination experiments* to disseminate tested methods, techniques or models through replication, which involves full-scale implementation of a technology.

Raven emphasises that experiments and niches are not the same. In niches the "local experiments and practices are compared, lessons and expectations are transferred between locations, and delocalised general knowledge of the technology in question is formulated" (Raven, 2005:38). And he highlights that experiments reflect three main evolutionary and sociological aspects of niches:

- Experiments bridge the gap between variation and selection environments: "Interaction between technology actors (firms, research institutes), societal actors (users, environmental groups), and regulating actors (public authorities) may contribute to integrating the concerns of different groups into the design" (Raven, 2005:38);
- Experiments are protected from some of the rules that make up the dominant socio-technical regime: public authorities give subsidies for lowering risks for involved firms and firms may decide to test the feasibility of a technology in a pilot plant because of strategic decisions;
- Experiments are often characterised by limited structuration and high uncertainty, especially in early stages of experimentation.

Rip emphasises that there is no linearity in technological development (Rip, 1995). This has been confirmed by Geels and Raven for a study of Dutch biogas development (Geels & Raven, 2006). Raven shows with a comparative case study approach for biomass technologies in Denmark and The Netherlands that the development of technological niches towards protected market niches and dedicated market niches and eventually regime shifts follows no linear patterns (Raven, 2005:253). Successful niche developments show a more parallel development pattern than unsuccessful developments: instead of one sequential attempt a technology is applied in an increasing number of geographical locations and application domains, by different actors and under different circumstances. These technological variations enable broader and faster learning and the possibility for spill-overs from one trajectory to another. Firms and policy makers are enabled to follow back-up strategies in the case of parallel development patterns (Raven, 2005:253). Beside the technological variations do the varying local context conditions play a major explanatory role (Coenen, et al., 2012).

Instability at the regime level increases opportunities for niche development, which can result in increased niche size. Raven distinguishes between three possible avenues: (1) regime instability can create local opportunities for experiments and niche actors develop expectations linked to regime instability; (2) with a decreasing stability of the regime the regime actors become interested in the niche because of promising options for the future; and (3) in the case of very high instability of the regime a niche can be adopted by the regime as a problem solver, but for this a sense of urgency has to become prominent in political visions and agreements (Raven, 2005:260).

However, the instability of the regime is not sufficient for niches to succeed. The quality of the niche processes is decisive. Following processes have been highlighted in the literature as decisive for successful niche development: facilitating learning processes, the formation of broad and aligned networks and institutional embedding, voicing and shaping of expectations and visions, and the development of complementary technologies and infrastructures (Hoogma, et al., 2002:30; Raven, 2005). In the following we summarize these processes.

Learning processes

Hoogma et al. point out that practical experience is necessary to generate knowledge required to accommodate introduction of new technologies – such knowledge cannot be acquired in house, but it needs to be tested in practice:

> “There is, therefore, always a need for an experimental introduction of novel technologies into use environments with the intend to learn … Often, niche activities are geared towards identifying and testing assumptions about specific advantages. Technological niches come about in the form of experiments, and pilot and demonstration projects” (Hoogma, et al., 2002:30).

Hoogma et al. highlight following aspects of learning as relevant for niches: (1) design specifications of technical development and infrastructure; (2) development of the user context, including user characteristics, their demands and their barriers to use the new technology; (3) the societal, safety and environmental impact of the new technology; (4) required industrial development, including production and maintenance networks to facilitate diffusion of the new technology; and (5) government role and regulatory framework in the introduction process, and possible incentives to stimulate adoption (Hoogma, et al., 2002:28).

Hoogma (2000:58) distinguishes between *first and second order learning*: “First-order learning refers to learning about the effectiveness of a certain technology to achieve a specific goal. First-order learning aims to verify pre-defined goals, to reach goals within a given set of norms and rules. Second-order learning refers to learning about underlying norms and assumptions and is about questioning these norms or changing the rules” (cited by Raven, 2005:42). These theoretical perspectives on first and second order learning base their definitions of learning on the early works of Argyris and Schön (1978) who describe a two stage reflective learning process. Hoogma et al. characterise first order learning in a niche as following: “various actors learn about how to improve the design, which features of the design are acceptable for users, and about ways of creating a set of policy incentives which accommodate adoption” (Hoogma, et al., 2002:28). They highlight that second order learning means to question and explore conceptions about technology, user demands, and regulations. “Opportunity emerges for co-evolutionary dynamics, that is, mutual articulation and interaction of technological choices, demand and possible regulatory options” (Hoogma, et al., 2002:29). While the concept of first and second order learning fits very well with a multilevel perspective, it can be argued that we need a more nuanced concept of learning if we are to understand what is happening in demonstration projects. Brown, Vergagt, Green and Berchicci (2004) have analysed higher order learning in bounded socio-technical experiments in personal mobility. Bounded socio-technical experiments attempt to “develop and introduce a new technology or service on a scale bounded in space and time” (2004:192). They are driven by long-term and large-scale visions of a more sustainable society. Brown et al. distinguish between two types of learning processes: "the first type occurs among the participants in the experiment and their immediate professional networks; the second type occurs in society at large", but they admitted that their cases did not provide much insight on the second type of learning processes (2004:191).

Raven emphasises the relationship between quality of learning (first order vs. second order learning) and the involved actors: "higher order learning and/or involvement of users and outsiders in the network improved the chances of a technological niche evolving into a market niche or becoming an element in a (new or existing) regime" (Raven, 2005:43).

Learning enables stabilisation at the niche level and is therefore the most crucial process for emergence of a market niche. Beside learning inside an experiment, learning between different locations and between different social groups is a prerequisite for the success of the niche (Raven, 2005).

Institutional embedding and aligned networks

Hoogma et al. identify three aspects of *institutional embedding* in niche development: (1) embedding includes the development of complementary technologies and the necessary infrastructure, (2) institutional embedding produces widely shared, specific and credible expectations which are supported by facts and demonstration successes, and (3) embedding ensures to include a broad array of actors aligned in support of the new technology – aligned network of producers, users, third parties, esp. government agencies (Hoogma, et al., 2002:29).

Coenen et al. emphasise the need for analysing institutional embedding in the geographical context for explaining "the extent to which and in what ways geographically uneven transition processes are shaped and mediated by institutional structures" (Coenen, et al., 2012:973).

Raven highlights that broad social networks include producers, users, regulators, societal groups and that these networks carry expectations and articulate new demands and requirements (Raven, 2005). There are two characteristics of networks which are important for niche development: (1) the composition of the network and (2) the alignment of actors' activities (Raven, 2005:40f.).

Regarding the *composition of the network* actors have to be included who are willing to invest in maintaining or expanding the niche. These may often be large established firms that support the incumbent technology regime and there is therefore a risk for defensive behaviour. A dominance of established firms can lead to dominance of incremental innovations. The network should involve also actors who have no strong ties with the existing regime, but they have often limited resource mobilisation potential and may not be able to maintain the niche over long time. Important is the active involvement of users, both industrial users and costumers, but also the involvement of non-user groups that are affected by the impact of the technology (neighbouring residents, environmental groups, concerned citizens) (Verheul & Vergragt, 1995). Raven points out that traditionally SNM literature has focus on users for generating second order learning processes, but he emphasises that involvement of non-industrial users is not always that relevant for industrial niche projects. Here is might be more relevant to involve environmental organisations or concerned citizens representing the neighbours of an experiment. “Including these groups at an early phase of experimentation can result in the inclusion of their concerns in the innovation process and prevent societal resistance in later phases, through early adjustment of the design” (Raven, 2005:257). It is also a possibility that such actors can participate in the experiments, taking part in the organisation of the plant.

The *alignment of actors’ activities* “refers to the degree to which actors’ strategies, expectations, beliefs, practices, visions, and so on go in the same direction, run parallel” (Raven, 2005:40). Rip understands alignment as a concept “that indicates the mutual and well-functioning adjustment” of strategies and visions at the network level (Rip, 1995:424). Visions may differ significantly between established firms and new firms and the alignment in a network requires special effort. Rip points out the importance of macro-actors, such as large technology introducers, government agencies and other ‘general interest’ actors, and relatively independent, and specially constructed macro-actors like ‘platforms’ or mixed consortia (Rip, 1995:426).

Expectations and visions

Lente (1994) investigates the role of promises and expectations in technological development – how promises about technologies are converted into design specifications. Expectations and visions are constituent for technological development (Borup, Brown, Konrad, & Lente, 2006). However, expectation statements only contribute to the development of technology niches if they become a part of agenda building processes (Lente & Rip, 1998:222). Agenda building processes and expectations influence each other. Expectations get converted into requirements and task divisions at different levels: (1) at the micro level: specific ideas about promising search routes guide solving of specific problems; (2) at the meso-level: visions and expectations about functionality result in functional requirements; and (3) at the macro-level: the cultural level of expectations justifies technological development for achieving sustainable development (Raven, 2005:50).

Expectations change over time, alternating between hypes and disappointment (Borup, et al., 2006:290). When early technological expectations downplay organisational and societal factors the disappointments are inevitable. Expectations can be affected by experiments in three ways: they can become more robust, the quality of the expectations can improve and the expectations can become more specific (Hoogma, 2000). Shifts in expectations have triggered actors to search in different application domains, contributing to niche branching. However, shifts of niche expectations are mainly caused by external changes, e.g. policies, and only to some degree by internal learning processes (Geels & Raven, 2006; Raven, 2005). Raven concludes that “a broad set of expectations is important in the beginning of a niche trajectory (to allow a parallel and continuous pattern), but that expectations should be made concrete and tested in experiments along the innovation journey (expectations should be linked to experimental results)” (Raven, 2005:256). Geels and Raven (2006) summarise the effect of learning outcomes in comparison to initial expectations as following: In the case that learning outcomes validate and accept the initial expectations a new development cycle is initiated that enables further incremental refinement. In the case that learning outcomes are below the initial expectations “faith in the new technology diminishes and expectations decline” (ibid: 380). Eventually, new expectations will be developed and if those come on the agenda non-linearity occurs.

Coenen, Raven and Verbong emphasise that niche-experiments have to be “underpinned by a dynamic set of diverse but complementary expectations that are not fixed but are open to internal and external adjustments while at the same time providing a stable basis for collaboration and coordination within the niche” (Coenen, Raven, & Verbong, 2010:6). While SNM has had a focus on technological expectations, they argue for a broader scope of analysis and to explore the institutional framework which is tied to the locality of the experiments (ibid).

Complementary technologies and infrastructures

SNM aims not just to introduce a new technology but acknowledges also the need for complementary technologies and infrastructures (Hoogma, et al., 2002). Existing infrastructures are not adapted to the needs of the new technology, and complementary technologies often have to be developed or at least to be adapted to the needs of the new technology. Regarding infrastructure, new distribution systems have to be established and maintenance requirements have to be introduced and the work force to be introduced for the new technology (Hoogma, et al., 2002). Investments in the old infrastructure constitute a strong lobby for own, and probably diverging, interests. The value of the new infrastructure and maintenance investments is often rather high and requires therefore decisions and collaboration on cost defraying. This issue is especially important when large technological systems are to be changed, as is the case for energy infrastructure (Hughes, 1987).

Outcomes of SNM

Hoogma et al. summarise four possible outcomes of SNM:

1. “Technological niche remains a technological niche through the set-up of follow-up experiments. This might involve branching to a new application domain and replication in similar domains. Technological niche gestation might lead to expansion and upscaling of the niche.
2. Technological niche becomes a market niche. New experiments are not necessary any longer, but users start to recognize the advantages of the novel technology and suppliers are willing to invest in production on a small scale.
3. Market niche is expanding and branching in new directions leading to the emergence of new market niches.
4. Technological or market niche extinction. The novel technology fails to attract further support and becomes (again) an R&D option (albeit, this time less promising). Niche extinction does not imply that investments are lost. Many spillovers in terms of network development, technical learning and reputation gains can justify the risk of having tried. In addition, learning

> that a certain technology development is not desirable is also part of SNM" (Hoogma, et al., 2002:31).

Geels and Raven highlight some changes in the analytical core of SNM (Geels & Raven, 2006). They point out three aspects: (1) the distinction between the global and local level of niches, (2) a shift of focus from individual projects to multiple projects, and (3) more attention to the "interactions between the three niche internal processes (learning and articulation processes, building of social networks, articulation of expectations) and how this results in innovation journeys" (ibid: 378).

There exist a number of critiques of the MLP which have been addressed by Smith, Voss and Grin (2010). Here we want to address one of these issues – the interaction of multiple niches and multiple regimes (see also Raven & Verbong, 2007). Niches compete with each other and they are positioned differently in relation to regimes. And a niche can relate to different regimes. Such multiple relations make the system quite complex. In the InnoDemo project this will have some clear importance and requires further reflection. As an example we can take biofuel niches. They have to fight the petroleum industry, but are using often their retail system for selling the biofuel; they have to relate to different sectors providing the resources, such as agriculture, forestry or the waste sector, and they have to relate to the automobile industry, that the produced biofuel can be used in the cars. And the biofuel niches compete with each other: bioethanol, biodiesel or biogas follow rather different avenues.

Large Technical Systems

The MLP framework has taken up important elements of previous work in the field of large technical systems (Hughes, 1987) concerning the interrelatedness of different components, both technical and non-technical, in large technical systems (LTS) as well as its rigidity to change. Joerges defines LTS as:

> "systems of machineries and freestanding structures performing, more or less reliably and predictably, complex standardized operations by virtue of being integrated with other social processes, governed and legitimated by formal, knowledge-intensive, impersonal rationalities" (Joerges, 1988:23f.).

Hughes emphasises that LTS contains a broad range of components which are "both socially constructed and society shaping" (1987:51). LTS include physical artefacts, such as electricity generators and power line systems, organisations, such as utility firms, manufacturing firms, banks, books, articles, research programmes and also legislative artefacts. And if natural resources are socially constructed and adapted, they are also system artefacts.

Hughes has analysed the patterns of evolution of such systems and has identified following phases: invention, development, innovation, transfer, growth, competition and consolidation. However, these phases are not simply sequential. They can overlap and there can be backtracks (1987:56). Radical inventions have started the system, but they are not possible in a mature LTS because they would not contribute to the growth of the existing technical system, but would overthrow it, and "conservative inventions predominate during the phase of competition and system growth" (1987:57).

For the growth of a LTS there are two phenomena important: (1) problems which function as “reverse salient” for the system, and (2) the momentum of the system. For our analysis are reverse salient especially interesting. Reverse salient are system components which have fallen behind and obstruct the system, they have to be addressed in new technology development. This means, that niches could be developed which provide (conservative) solutions for the problem inside the LTS. They could be integrated into the existing system. Alternative, more radical solutions could turn over the existing system if they would succeed. The existing LTS acquires momentum, the involved organisations and people have often “vested interests in the growth and durability of a system” (1987:77). Both reverse salient and the inertia of the system caused by the developed system momentum make niche development inside an existing LTS difficult (Hughes, 1983, 1987).

Hughes has developed the concept of LTS by analysing the history of the electric light and power systems in the U.S., the United Kingdom and Germany, but he also has acknowledged that similar systems, structures, relations and processes can be found in other industries, such as chemical industry, automobile industry or the telecom industry (Hughes, 1987). Analysing the role of demonstration projects for innovation to promote the transition to sustainable energy and transport requires therefore taking into account the specific scale and development patterns of these systems. They are different compared to smaller technical systems which have not amassed momentum in such a high degree as these LTS and which are therefore easier to change.

Joerges distinguished between LTS and major types of subsystems: large technical networks (LTN) and large technical programmes (LTP) (1988:27). For this paper LTP are especially interesting. Joerges sees LTPs as “pre-infrastructural systems oriented towards some quasi-experimental set of technical and economic goals” (ibid:28). LTPs involve multiple government agencies, and they can have a transnational scope. They often are undertaken to radically expand or transform existing LTS and a LTP might be called a “forward salient”, an analogy to Hughes “reverse salient” coined by Joerges.

Conclusions

This paper addresses following three main concerns:

Firstly, it focuses on demonstration and trial projects, targeting core processes and key instruments needed to facilitate the alignment of promising new technologies with societal conditions. Such alignment is necessary for the successful adoption of radical new technology and if the development and diffusion of emergent technologies, in a transition to more sustainable energy and transport systems, is to be sustained and accelerated. Trial and demonstration projects act as ‘market engagement programmes’ which support field tests of new technologies and provide data on their performance in target applications (Grubb, 2004). They have proven to be an important instrument both for policy-makers, researchers and firms in helping to reduce uncertainty and learn about the acceptance, desirability and adaptation of new technology in society. Interaction with societal actors, monitoring experiences with governance of such projects and policy learning are all important issues.

Secondly, it addresses technologies that are promising platforms for a transition to a more sustainable energy system and transport system, such as renewable electricity, hydrogen, and sustainable biofuels. The future development pathways of these technologies are challenged by a high degree of technological, social and economic uncertainty as well as durability of the incumbent fossil-fuel based energy and transport system. It is this 'systemic lock-in' that means that the deployment and diffusion of sustainable energy and transport systems is often hampered by market failure, and thus requires policy support.

Thirdly, the measurement of the tangible and intangible outcomes, intended and unintended effects and long-term impacts of trial and demonstration projects can provide important insights for policy makers. Countries have invested heavily in trial and demonstration projects for sustainable energy solutions over recent years. This makes it crucial to understand why certain projects do or do not succeed. Success can be measured by comparing the objectives of the projects and the achieved outcomes of the project. Intangible learning outcomes are important here (Kamp, et al., 2004), and strengthened networking between firms, technology providers, authorities, user groups and other stakeholders (Hoogma, et al., 2002). The understanding of relative failure might also be a first step towards better solutions (Karlström & Sandén, 2004).

This literature review will guide the InnoDemo project answering our research questions:

1. What are the main contributions of Scandinavian demonstration and trial projects and programmes to sustainable energy and transport transitions?
2. How should the governance of such projects and programmes be developed to further support their contribution?

Answering these questions requires a clear understanding of "sustainable energy and transport transitions". This was the objective of the second part of this literature review positioning this project in the context of Strategic Niche Management theory. SNM has a focus on learning processes, institutional embedding, aligned networking, expectations and visions, and complementary technologies and material infrastructure.

We understand demonstration projects and trials as experiments to overcome uncertainties, while uncertainties can be of different character, such as technological, costs, environmental, social, political etc. Such projects exist at different scale, including a variety of types of actors, and they have different objectives and different types of outcomes. A comparative analysis of demonstration projects and trials has to ensure that projects are comparable according to objectives, organisational solutions, and technologies. We distinguish between following aims of demonstration projects and trials, but most of the projects will have several aims:

- prove technical feasibility,
- contribute to the formation of knowledge networks,
- facilitate learning that can be instrumental for decisions on technology choice and can form a starting point for advocacy coalitions,

- reduce building, materials, components, operating and maintenance costs,
- prove feasibility in commercial applications,
- prove environmental feasibility,
- develop public acceptance and awareness,
- expose system weaknesses such as various institutional barriers, and
- introduce institutional embedding for societal change.

The most important outcome is learning, but here we can distinguish between first and second order learning, and between learning processes related to STI and DUI modes of innovation. The dissemination of the learning outcomes is a major issue for the success of governmental funded demonstration projects and trials. Currently, there is not *one* theory or concept of learning which covers all the potential learning processes in a demonstration project. More work needs to be done in this area in order to make the complex and extensive learning processes occurring in demo projects more visible to participants and stakeholders. Following and expanding Hoogma et al. on learning in niches we will analyse following aspects of learning as relevant for demonstration projects and trials:

- design specifications of technical development and infrastructure,
- development of the user context,
- the societal, safety and environmental impact of the technology,
- required industrial development, including production and maintenance networks to facilitate diffusion of the new technology,
- interactive learning between the partners in the projects,
- policy learning on government role and regulatory framework, and possible incentives to stimulate adoption after the demonstration project.

The literature review revealed following conclusions regarding the governance of demonstration projects and programmes. Here we highlight following issues for programme managers:

- user involvement is crucial at all stages of demonstration projects to facilitate information and learning,
- project design should not be rigid to allow user input and modifications to improve effectiveness,
- careful planning to take account of market readiness and user participation,
- considering the required size of the projects,
- dissemination of results and evaluation information should be included in the project design,
- projects should ensure in their budgets performance monitoring, maintenance and trouble-shooting, which are all essential for learning,
- the programme should be clear about the maturity of the technology to be demonstrated subsidies for demonstration projects and trials of new generations of technology should not be used for the older generation of technology.

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Taking issue with social sustainability in Urban Transition

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Abstract

The politics of urban sustainable transition is becoming increasingly complex as many cities find themselves articulating the tripod of economic, environmental and social sustainability yet a time are unable to tackle an increasing segregation and deeper social gaps leading to outburst of violence and continual unrest underlining that focusing on energy renovation will not suffice.

This status leads the present paper to ask for new possibly innovative approach to urban transition. It is suggest including young citizens experiences in the landscape of interests necessary to provide the governance. The paper analyzes the lived and narrated experiences of three persons, teenagers of the built environment of deprived suburbs of Swedish cities and towns, using two novels and a biography. They tell us about experiencing if not poverty then serious lack of resources, a feeling of being in the periphery vis a vis the center of town, a series of violent experiences of drug addicts, physical violence also in their families and a feeling of displacement from one’s origin. But also strong feeling of identity being with friends of the same age.

The implications for urban transition is to use a more sensitive and long term set up for developing neighborhoods in a social sustainable direction. It will require a broad social alliance to bridge political and sectorial fragmentation and downplay short term goals.

Introduction

Global cities are struggling to associate urban renovating with sustainability. Suburbs created in the postwar period are in serious need of physical renovation but many are also facing important social problems such as segregation, unemployment, crime and unrest. To answer these problems, urban planning tends to focus on economic, environmental and architectural solutions to the detriment of social concerns. A focus on functional provision of employment, social infrastructure and leisure facilities is not enough to rehabilitate the deprived neighbourhoods. Moreover many urban regeneration projects have tended to reduce the citizen to a statistical category (Swyngedouw et al 2002) or to reduce social sustainability into controlled participation (Valdes-Vasquez and Klotz 2013). And it is mostly adults representatives which participate, counter to the age profile of the suburbs (Andersson et al 2009, Colantinio & Dixon 2010, IMA 2009) Renewing projects could include social sustainability concerns such as disparity and segregation between rich and poor areas, social diversity or community cohesion. However if these issues cannot be solved by realising new infrastructures how can urban renewing then address these concerns?

In order to identify new possibilities of including social sustainability in urban regeneration, inspiration could be taken from approaches to social innovation (Dawson 2010) and user driven innovation Von Hippel 2005), emphasizing the local experiences of neighborhoods i.e. the products of urban transition, by giving voice to their users. The aims of the paper are thus to answer the following questions:

Which are the qualitative characteristics of the deprived suburb neighboorhoods as perceived by selected former inhabitants through their literary account of their youth?

How do these accounts contribute to the understanding of especially social sustainability?

The paper discusses how the inhabitants experience these areas and which markers are associated to the/different places, their accounts are collected through their discourse and then compare to the issues of new research contributions on social sustainability (Bridge et al 2012, Broström 2012, Colantonio and Dixon 2011 a.o.). Leading to take issue with poverty and segregation amongst others.

The empirical field is the Swedish development program “Million- program” and the discourse about its needed transition into sustainable neighborhoodds. During the year 1965 -1975, 70 000 dwellings were completed annually to reach one million new dwellings addressing housing shortage. The suburb areas created under that program in the sixties are receiving current attention in terms of policy and resources in an attempt to (arguable) enable a sustainable transition. It seems however if the construction and housing companies are well equipped to repair the physical depletion of these areas, they lack of competences regarding social issues.

Using a discourse analysis, the empirical material provides a bottom up perspective built on the following three citizens narratives: Alakoskis (2012) tells about her own childhood and homeless people living in her neighbourhood of “new Fridheim” in Ystad in southern Sweden. She uses a mixing of biographical material, political commentary in the form of a dairy. Lagercrantz (2011) relates the biography of an immigrant boy breaking out of the suburb environment Rosengård in Malmö and becoming a football star. Olsson (2012a) tells about a teenager growing up in the suburbs Gårdsten and Bergsjön outside Göteborg accounting for her teenager years and her discovery of the city centre as opposed to her own suburb.

The paper is structured as follows. First the theoretical framework focusing on the social sustainability element of urban transition and using critical discource analysis is outlined. Then a method section is discussing use of abduction, selection of the text used and the strength and limitation of the approach. Then the social sustainability dimensions and their counterpart/contrast is structuring a presentation of elements of text from the three books. Finally a discussion and a conclusion summon up the analysis and the results.

Theoretical framework Urban Transition

Transition theory (Geels 2005, 2011, Bergek et al 2008, Jacobsson and Bergek, 2011) encompasses broad views on societal change, yet tends to focus on the business and societal institution aspects of community development. Here the citizen is in focus implying a shift in emphasis. A number of approaches to sustainable community development and urban transition has been mobilized to understand the development of cities including approaches such as engineering (systems theory) Maas et al (2012), neoliberal (Swyngedouw E et al 2002), Cultural/sociological (Czarniawska 2001) and integrated multiple perspectives (Colantonio and Dixon 2010).

Social sustainability is a contested term as diverse interests inscribe themselves in it. Even if most contributors connect social sustainability to environmental and economic sustainability, referring to the Brundtland report, a plethora of different understandings of persist (Boström 2012, Colantonio and Dixon 2010, Dempsey et al 2009 Olsson 2012b). These authors provide several definitions and a number of aspects. Colantonio and Dixon (2011:8) show how a number of interests and communities are in tensions on the shaping of concepts including

-Property led physical approach. Retail led or mixed use scheme expected to have multiplier effect (Dixon and Marston 2003)

-Business driven approach, the importance of underserved markets, particularly in inner city areas

-Urban form and design perspective, which highlights the importance of the relationship between sustainable development and Urban form

-Cultural industries approach

-Health and well being perspective

-Community- based, social economy approach

Based on discussing these perspectives and Colantonio and Dixon (2011) suggest the following definition of social sustainability:

"concerns how individuals, communities and societies live with each other and set out to achieve the objectives of development models that they have chosen for themselves, also taking into account the physical boundaries of their places and planet earth as a whole" Colantonio and Dixon (2011: 8).

However drawing on Sachs' (1999) which view socioeconomic development as an open ended historical process, which partially depends on human imagination, Colantonio and Dixon (2010) suggest that social sustainability should be "interpreted as a socio-historical process rather than an end state" (Colantonio and Dixon 2010: 21, see also Dempsey et al 2009). This lead into thinking of the definition as contextual in space and time. Drawing on the Bristol accord developed in town of Bristol, Colantonio and Dixon (2010) provide a particularly strong programmatic statement of social sustainability. This accord proposes the following eight characteristics of a sustainable community:

- Active inclusive and safe
- Well run
- Environmentally sensitive
- Well designed and built
- Well connected
- Thriving – with a flourishing and diverse local economy
- Well served
- Fair for everyone

(Colantonio and Dixon 2010: 33)

We find these inspiring and comprehensive and use them below in the analysis.

Following Colantonio and Dixon (2010) and Dempsey et al (2009) one should strive at being contextual. Therefore prevalent understandings are those contextualised to Göteborg, Malmö, Ystad and Sweden. Professor emeritus S. Olsson is collaborating with the city of Gothenburg, with his understanding of social sustainability published in the present essay on their website (Olsson 2012b). His discussion of social sustainability is nevertheless internationally well informed judged by the references used. Olsson (2012b) suggests understanding social sustainability in two main dimensions welfare and problem solving capacity. The welfare dimension consists of a justice and a satisfaction element. Justice is further conceptualised as equity, democracy and mixity drawing on Fainstein (2010). Olsson mentions segregation as an important Swedish problem, but downplays exclusion.

The problem solving capacity of a society depends on its various social systems and how they tackle societal challenges (Olsson 2012b). It relies on the single persons initiative, cultural values and control mechanisms within politics and societal institutions. Olsson (2012b) claims that Sweden at least to some extent is an active society, with high capacity of problemsolving.

Boström (2012) in his discussion distinguishes between content and process. In terms of content he refers a large number of criteria including basic needs, access to infrastructure, social cohesion and inclusion largely compliant with the Bristol accord. In terms of process he mentions participation in the sustainability project,empowerment, accountable governance and management. Boström is researcher at Lund University close to Malmö and Ystad.

Summarising social sustainability is a multifaceted concept, that should be viewed in a contextual and processual manner. Whether a neighbourhood is social sustainable or not in the Swedish suburb context could then be discussed using the Bristol accord dimension and its counterparts combined with Olsson (2012b) idea about problemsolving capacity. A dimension like “active inclusive and safe” is therefore here used as segregation and violent experiences. And “fair for everyone” is discussed along with problem solving capacity related to unfair events. Here we leave the processual part behind us as the analysis is confined to texts.

Critical Discourse Analysis

Critical Discourse Analysis (CDA) study texts to reveal the discursive sources of power, dominance, inequality and bias Fairclough 1993, Sheyholislami 2002). It examines how all types of text, written, spoken and materialised are maintained and reproduced within specific social, political and historical contexts (Fairclough 1993). Where early CDA tended to focus on texts alone (Ferguson 2007), later versions extend the emphasis into communicative interaction trying to understand production *and* consumption of text (Chuliaraki and Fairclough 1999, Ferguson 2007), including the relation to an audience of the text and also pursuing phenomena of intertextualilty. Chuliaraki and Fairclough (1999) claim that

“CDA of a communicative interaction sets out to show that the semiotic and linguistic features of the interaction are systematically connected with what is going on socially, and what is going on socially is indeed going on partly or wholly semiotically or linguistically. Put differently, CDA systematically charts relations of transformation between the symbolic and non-symbolic, between discourse and the non-discursive”. (p. 113)

In this later version of CDA, there are three elements of analysis; texts, discourse practice and sociocultural practice. As it will follow, we are confined here to analysing the texts. Therefore
The following details the text element of discourse analysis and the intertextual analysis which here is related to interaction of text and the borderline between text and discourse practice.

According to Fairclough (1995) analysis of text involves first linguistic analysis in terms of vocabulary, grammar, semantics, the sound system, typically at sentence level and second cohesion and organization of the text as a whole. Linguistic analysis is applied to the texts properties of lexical-grammatical and semantic character as well as the intertwinedness between these two properties. Moreover sentences and text can serve several purposes and a multifunctional perspective is needed. Fairclough (1995) suggests that sentences in a text is analyzable in terms of their representations, relations, and identities. Representations reveals possible relations to social practice and can involve a particular (re-)contextualization of the social practice (Fairclough talks of an ideational function). Relations refer to a particular construction of the relationship between writer and reader and identities to the constructions of the writer and reader. Linguistic analysis is also concerned with framing i.e. inclusion and exclusion of elements of all three types in the text/discourse.

The intertextual analysis is counter to linguistic analysis more interpretive and less descriptive. In Faircloughs version the perspective of intertextual analise is from the discourse practice, whereas we here more adopts the type of text analysis sensitive to that texts feature mixing of several texts, importing elements from different sources, viewing this as traces of the discourse practices in the text (Fairclough 1993). There are two types of intertextuality: manifest and constitutive intertextuality. Manifest intertextuality refers to the h texts where specific other texts are directly inserted or referred to in other manners within a text. This can be detected by use of explicit signs such as quotation marks, references etc. Constitutive intertextuality refers to the heterogeneous texts composed of elements discourse or of orders of discourse, called interdiscursivity (Fairclough 1992). This kind of intertextuality refers to the structure of discourse conventions that go into the new text’s production.

Summarising critical discourse analysis view language and discourse as a social practice throught which the world is represented involving the exercise of power and domination. Our analysis aim at identifying the discourse in three texts using the part of critical discourse analysis directed towards texts. Sheyholislami (2002: 13) proposes a series of propositions for use of CDA and we use the following:

- Texts acquire their meanings by the dialectical relationship between texts and the social subjects: writers and the readers, who always operate with various degrees of choice and access to texts and means of interpretation.
- Linguistic features and structures are not arbitrary. They are purposeful whether

or not the choices are conscious or unconscious.

- Power relations are produced, exercised, and reproduced through discourse.
- All speakers and writers operate from specific discursive practices originating in special interests and aims which involve inclusions and exclusions.
- Discourse is historical in the sense that texts acquire their meanings by being situated in specific social, cultural and ideological contexts, and time and space.

This implies that there is not such a thing as the right interpretation as both authors and readers are actively participating in the creation of meaning.

Method

The overall theoretical, empirical and analytical approach is interpretive sociology using abduction in interaction between empirical elements and theory (Alvesson & Sköldberg 2005).

Theoretically we take point of departure in transition theory (Geels 2011 and Jacobsson & Bergek 2011), developing a review on approaches to urban regeneration and social sustainability.

Empirically a biography (Lagercrantz 2012), a biographical account in form of a dairy (Alakoskis 2012) and a novel (Olsson 2012a) of citizens of the neighborhoods of Miljonprogrammet in Sweden is used to provide a lived bottom up perspective of these neighborhoods. The three account each cover a suburb of Malmö, Göteborg and Ystad. These three accounts are selected for two main reasons. First because of their striking strong messages on life in suburbs. Messages which in contrast to other parts of the contemporary discourse of the renovation of these suburbs. Second because of the recent appearance; they were all published in 2012.

Olsson (2012a) is a novel about a girl, Miira, with Finnish parents. Her upbringing is followed from roughly 8 years from 8-16 during the 1980ties. The style is autobiographic and the chosen time period fit with the authors own childhood (Olsson born 1973). A dramatic style is used where almost every chapter is short and involves some kind of dramatic event.

Lagercrantz (2012) is a biography of Zlatan Ibrahimovic’, born in 1981 and living his childhood and teenager years in Rosengård in Malmö. He continues to visit the town even after becoming a professional football player in 2001 and the part of the biography, which is about Malmö and Rosengård thus covers twenty years. Lagercrantz is a well established biographer here constructing a biography in a straightforward manner, organizing Zlatan Ibrahimovic’ stories of his life. The story is very appreciative to the main person.

Alakoskis (2012) use a mixing of biographical material, even directly quoting a number of texts such as patient records of her father and mothers hospitalisations, contemporary political commentary and referencing other authors and researchers all compiled into the form of a dairy covering the month of October 2012. The printed book is shaped like a dairy would be. Alakoskis (2012) youth were spent in the southern Swedish town of Ystad (maybe known to a wider audience through the filmed novels of Wallander by BBC). She was born in 1964 and later educated as social worker and as author she has written a series of successful novels. The million program neighbourhood she grew up in is ”Nya Fridhem” with 264 appartments and built in 1964 in Ystad.

The narratives are analysed looking at concepts such as poverty and segregation using discourse analysis (Fairclough 1992, 1993, 1995). Using critical discourse analysis on novels is unusual, but straightforward as texts are central objects. We argue that the three texts are part of the discourse of the renovation of the million program in Sweden. The approach adopted parallel Hassard and Halliday (1998)’s set of analysis of films and novels representing discourse on organisations. Hassard and Halliday (1998) claim that the strength of literary forms like novels is that the full energy of peoples lived life is included in the narratives of the phenomena counter to more dry and clinical and distanciated scientific genres. The limitations relates to the strong personal approach the text represent. The selection of event and their presentation is beyond the reader and researchers discretion. The claim of such analysis is therefore modest. The discourse they mobilize is perspectives on social sustainability, which have illustrative character. Moreover all three authors look back to periods in the past, whereas the upcoming transition of the million program is a contemporary process. Alakoski (2012) appears very conscious on this and establish the link through using manifest intertextuality (Fairclough 1993) between contemporary commentary of political manifestos type and the biographical accounts of her youth. Alakoski, Olsson and Ibrahimovic’ are all exceptions in their neighbourhood and think of themselves as such. Their social ascent at a time limits the value of their account and enables it.

The analytical limitation encountered is that the present piece use text only and is not including the broader social discourse and discourse practice neither how the readers would receive and interprete a text like those analysed here.

Cases

Below the three cases are presented structured according to themes occurring in the discourse echoing and/or contrasting the social sustainability dimension given above. This includes basic needs, violent experiences, segregation poorer education, segregation centre-periphery, justice/problem solving capacity. But we open with the first characterisation the authors give of the neigborhood they tell about:

In Olsson (2012a: 25) the main character Miira describes her home area of Gårdsten, Gothenburg;

“ *this place is called Gårdsten because the places are covered with asphalt, the highrises with concrete and there are stones on them everywhere and the faces are hard as stone*”

This is where the Finnish minority lives:

“….In the bus was sitting Jaanas mamma and other Finns. All Finns went to Gårdsten. They lived there. The finnish accociation was there, the social club house, that daddy contributed to and where he and the other internal finns were exercising, bathing and partying. In Gårdsten was even the special school classes for finns with teaching in Finnish” (Olsson 2012a: 26)

Zlatan describes the diversity of nationality backgrounds first, when charactrerising Rosengård (Lagercrantz 2012: 64).

Alakoski characterise the building blocks that constitute the neighborhood of Nya Fridhem in Ystad as the ”pig wings” referring to where pigs would be placed in a farm.

Basic needs

Alakoskis (2012) continually tells on homelessness, begging in the street when using contemporary time. She are emotionally disturbed by the people “sitting on their knees” in the street and often give them money (Alakoskis 2012:13). However the biographical part of the youth in Ystad is different. There poverty is mixed in with a series of other issues the family has to tackle.

Olsson (2012a) is portraying the family as having their basic needs covered. The parents have employment, the father at a car factory and the mother as cleaning lady. The teenage daughter has her own room in their apartment. Nevertheless the young teenager feels she has to steal to supply herself with clothes

Similarly Lagercrantz (2012) describe the Ibrahimovic family as having employment, some space, but also how drug addiction and deroute challenges the family. And how the fridge of Zlatans father is often empty requiring improvising of the boy. And the boy lacking resources when being with his football mates (Lagercrantz 2012:89):

“But I could not measure up with my mates; “ come along Zlatan, we take a pizza, a burger, we go and by so and so”

“Ah…later I am not hungry, I pass”

I tried to linger around it and be tuff anyway. I didn’t manage”

For Zlatan the lack of resources is also a marker of being different to his team mates (Lagercrantz 2012:89).

Violent experiences

Olsson (2012a)'s main character Miira presents a bomb threat to her school, witnesses a teenage getting beaten (dying afterwards), setting fire to a forest, files a fire alarm on her school. Experiences an adult using free liquor to get sexual services from the minor.

Alakoskis father is an alcoholic, her mother gets beaten up on several occasions and hospitalised so is the father, in a psychiatric section (Alakoskis 2012). Her youth friends, especially the boys, are becoming drug addicts and small size criminals, one even a murderer.

Segregation poorer education

At the seventh grade Olssons' classes are split in "common" and "special". The pupils are supposed to choose themselves (Olsson 2012a: 199-200):

"Pekka (the teacher): You, which think you are good, chooses "special" and those that know you are bad chooses "common". Special is difficult and "common" is easy".

She was not in doubt made the cross at special in both topics

"What did you choose?" she asked the girls. "Common" they said simultanously. Jaana levered her eye brows and looked at her as if the answer was given, the question unnecessary. "didn't you?"

"Na". She turned to the boys and asked the same question. "special" they all said.

…

Taking a cigaret outside the building Miira remarks *"you are going to be burned if you go there, why did you do that?*

"I am bad at math" said Jaana, *"me too"* said Niina*"*

Segregation centre periphery

Miira and her close friend take the bus and a tram to the centre of town. They have to change at Angereds centrum. Miira feels her body language changing into a more stiff expression:

”Looked at the people. There were a shitty lot. Most of them snobs. The snobs were smarter and boasters and grown-up minis that had become older…. The jeans fitted perfectly on the snobs. Slim. They had waist short leather jackets with shoulder pads and some of the leather jackets with fringes. Their hairdo was fresh, they had hair highlights done at hairdressers and finely sprayed. The makeup sat like on models and the lips were elaborately painted with lipstick or gloss without glitter. They moved their hands smoothly.

She looked discreetly down herself.

The college pants did not fit perfect. No clothes fit perfect on her. They were puffy…..” (Olsson 2012a: 125). The people in town move their hands in a fine elegant manner:

“In Gårdsten nobody moved their hands smoothly. There they hanged down from the elevated under arms as if the wrist had gone of.” (Olsson 2012a).

Zlatan also experience living in the periphery, as a kid and teenager he lives in Rosengård, which he dscribes as outside Malmö, and do not enter the center of town until late in his teenage development:

….but I had no clue where the football stadium was, or anything else, for that matter, in town. Malmö was rather close. But it was another world. I was seventeen before I got into the centre, and I understood nothing of the life there” (Lagercrantz 2012:86)

Justice / Problem solving capacity

Olsson (2012a) provides quite a lot of examples of the society’s provision of services to the young schoolkids, some of them fails others have some success, such as systematized feedback to the parants (Olsson 2012a:85):

Haggan, the teacher gives the following written notice to the parents of Miira*:*

”Miira is very hardheaded and difficult to call to order. Talks loudly. Argues allways against, but does in the end as we say”

Such reports are supposed to be signed by the parents, but Miira destroys it, by penetrating it with her fuck finger, speculating that the parents won’t find out.

Miira handles in a bomb threat to the school, writing on a piece of paper ”bomb” and attaching to a door.Then watches from a distance how the fire brigade and the police arrives (Olsson 2012a: 89).

Ibrahimovic is threatened by his team mates’ parents gathering signatures against his participation on a youth football team, yet is protected by the trainer (Lagercrantz 2012:87):

There was already som foreigners, Tony among others. Apart from them it was only Swedes and some was Limhamn types, upper class kids. I felt like coming from Mars. Not only because my father did not have a nice villa… I was talking differently.

It began smouldering amongst the Swedes. Their parents wanted me out… Some idiot of a father gathered signatures. Zlatan has to go it said. All kinds of types signed that list.

The coach Åke Kallenberg just stared at the piece of paper. What kind of weird shit is that. He tore it apart."

Alakoski (2012:37-38) describes how her brother "fleed into abuse" of drugs and alcohol for thirty years. "He cost society" a lot. But " then the miracle came", somebody cared, a social worker Thomas made the difference and dragged the brother out of his abuse.

Displacement and its decay

All three narratives encompasses families which moved far from their homeland to seek job and/or fleeing from war. Ohlsson (2012) and Zlatans parents have a long an lasting feeling of displacement, listening to music from their homeland (Finland and Bosnia), Zlatan refers to "papa and his jugge music"(i.e. Yugoslavian music, Lagercrantz 2012), Olsson refers to Finnish and Russian music, finnish grill sausages and other symbols of Finnish culture (Olsson 2012a). The parents follow the development of the countries through the TV (Lagercrantz 2012), participating in associations of fellow citizens coming from the same original countries (Olsson 2012a).

However when it comes to the second generation, their socialisation outfolds in a different manner. They appear to build their identity in multicultural, Swedish context, which leads to a decay of the feeling of being away from ones homeland, yet still part of a segregated minority. Zlatan describes it like this

"I Rosengård we had various yards and no yard was worse than others, well the one with the gypsies had low status… It was the yard that counted not which country your parents came from" (Lagercrantz 2012:82)

And phrases a slogan " *you can take the boy out the ghetto, but never take the ghetto out of the boy*"(Lagercrantz 2012:62).

Whereas Olsson (2012a:85) describe up around eighty national groups placed in the neighbourhood, with most finns, and that did not relate much to each other and with strong sense of belonging internally in the Finnish/Swedish group.

Discussion

The following is structured as follows: first the dimensions of the discourse on the neighborhoods is discussed one by one presented above is discussed. Then a crosscutting discussion is carried out.

Alakoskis, Olsson and Ibrahimovic accounts are very personal and involves love stories and the importance of the social network, which are described as very important for the main figures. Alakoskis is using intertextuality a lot mixing presence and past, biographic elements and political commentary, telling several stories (ie. on contemporary poverty, on experiences as an author, as teenage girl with her parents and more).

Basic needs/poverty

Where Alakoski (2012)-s account is far more in a hopeless vein than the two others, they all show that employment did not prevent the harsh environment to develop. Neither did the presence of schools and other social infrastructure. The main characters have parents with employment and as kids they have their own room in the appartments they live in.

Olsson and Ibrahimovic describe how theft and stealing is understood as something you do to compensate for lack of resources. Olsson (2012a) recurrently describe how the friends share their rare goods, be it cigarettes, alcohol or more. For Zlatan the lack of resources is also a marker of being different to his team mates.

Segregation

Gårdsten is described as not only sheltering a Finnish minority, but also a number of other minorities.

Rosengård is described as an ethnic melting pot, where location in the neighbourhood of Rosengård counts, not previous nationality, with the exception of the gypsies.

For both Ibrahimovic and Olsson the use of a particular language, saturated with slang underlines a cultural, discoursive segregation.

The Finnish minority is treated in a paternalistic manner (a finding similar to that of Kalonaityte 2010). The Finnish kids are funnelled into special classes, where their Swedish are developing poorer than for the native swedes. The social inheritage is thereby reproducered rather than broken. Also expressed in the choice of education.

Mechanisms of segregation are at a time outspoken and subtle. Olsson accounts for special language classes and geographical distance to the center of town as two.

Compared to public reports on segregation (Andersson et al 2009,Salonen 2012), the concentration of foreigners in some neighborhood are getting stronger and distance between rich and poor neighborhoods in the Swedish cities of Göteborg, and Malmö are becoming bigger.

Centre-periphery

The main characters describe their stirred up feelings of entering the center of town. Its an experienced distance by the inhabitant youngsters more than a natural one. Rosengårds distance to the center of Malmö is some 6 kilometers, and Gårdsten has relatively good public transport connection with Gothenborg center with a distance of 15 kilometers. But the feeling of cultural difference by the teenagers are strong.

Justice/ Problem solving capacity

Olsson (2012a) recurrently give examples of extra resources offered to the youngsters, and how they are not able to administer them. It appears more to be an issue of embedding the offers in the social culture of the teenagers, than the good will of the offers seen isolated. It is a clash of a “good will” discourse and a discourse of “us and them” viewing all institutions as an adversarial system. When problem solving capacity is mobilised it appears to build on civil society efforts, even down to single persons such as Zlatans coach disregarding a petition or Alakoskis brother being saved by a social worker and Olssons Miira figure being encouraged by a temporary substitution teacher. This is parallel to Olsson (2012b) argument

The overall discourse provides a complex qualitative picture of the characteristics of the deprived neighboorhoods. As also Öresjö (2012) has remarked these neighbourhood does not automatically encompasses social environments that are not sustainable. Transition projects focusing on energy renovation risk to erode or even destroy social capital of these neighborhoods. If energy renovation is done on a business basis real estate owners are likely to strive on upgrading neighborhoods asking for higher rental, which would tend to push the lower income groups out (Öresjö 2012).

The city councils and a range of other players have continually over the last thirty years (at least) launched public initiatives to handle the issues or at least create legitimation that something is done. Currently both Göteborg and Malmö are having a whole range of such initiatives, one example is “Bergsjön 2021” communicating initiatives of this deprived neighborhood outside Gothenburg (Bergsjön 2013). Öresjö (2012) reports that a remarkable large part of such improving projects have failed (with reference to Vidén et al 1990), because there has been a too strong emphasis on new built and real estate company¨s interest when renovating. Therefore the lived experiences discourse presented here appear to stand in contrast to urban planners helicopter's view, privatization and halfhearted participation schemes in social sustainability schemes. Nevertheless Colantinio and Dixon (2010) and Törnquist (2012) with a European outlook claims to find examples of social sustainability improvements in neighborhoods in a series of European cities. Friesen et al (2012), Öresjö (2012) and others have also tried to establish such examples in the million program context, yet using the less deprived areas as case field.

Transition theory approaches would inform urban regeneration projects by underlining the broad and multifaceted societal alliances need to progress urban transition (Maas et al 2012). There is a need to overcome policy fragmentation and other aspects of city regimes.

There is an echo of the juxtaposition of an incumbent regime and an upcoming niche in the constellation of an urban constellation of actors focusing on making cities competitive and facing competing agendas of social sustainability from groups of citizens, which appear poorly articulated

Creating sustainable cities in all three dimensions; economic, environmental and social appear to require an unusually broadly orchestrated set of efforts and resources. Along with Colantinio and Dixon (2010) the analysis here point to soft aspect of social sustainability; levering social capital and changing local cultures. More instrumental solutions such as mixed housing can trigger such developments, but cannot stand alone as Bridge et al (2012) also shows.

Conclusion

This paper set out to scrutinize which the qualitative characteristics are of the deprived suburb neighboorhoods using the approach as give voice to perceptions of selected young citizens, viewed through their own accounts. And also with the intention to compare to recent research contributions especially on social sustainability.

Using an abductive approach the paper has proposed a series of dimension of social sustainability, yet also insisted in the concepts contextual and processual character. Adopting critical discourse analysis on three texts on how it was experienced living in the context of the million program.

The analysis has shown a more cultural and social poverty and feeling of being peripheral related to soft issues. Basic needs are covered but the youngsters feel poor. Feeling peripheral cannot be counted in bus and tram connection and/or kilometres. The youngsters *experiences* the distance. Violent experiences become part and parcel of this culture. Justice and problem solving capacity is limited for a number of reasons. Many societal efforts appear to fail amongst the youngsters.

The accounts urge people in charge of urban transition to better understand the complex and more culturally oriented set of challenges in creating social sustainability. To create social sustainability is a long and multifaceted process requiring a broad alliance of public, private and third sector players.

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States as "niches" in low-carbon transition governance? An attempt to (re)think transitions in a transnational governance perspective[1]

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Abstract

Can smaller countries play the role of niches in global climate transition governance? If they can, on what basis can they act as niche actors, or pioneers? This article suggests that specific progressive states can act as forerunners and be viewed as 'niches' in the international system through their transnational activities. Through these research questions the paper considers the concept of niche players in light of similar concepts like pioneers and forerunners and relates it to the state as an actor. It takes the starting point in an earlier literature about the role of forerunners or pioneers in international and EU environmental policy making, which argued that certain states had considerable influence on policy making. These forerunners act based on their previous experience with solutions and strategies often in the domestic or subnational context. The findings in theses literatures are juxtaposed with scholarly work on the role of niches in transition processes and form the theoretical base for an empirical analysis of current climate policy making in Sweden. The study elaborates on Sweden's forerunner role as an example of how niche behavior can be conceptualized in the context of the transnational.

Introduction

In a recent paper presented at the International Studies Association[3], John Grin argued for the need to conceptualize the transnational dimension of the governance of sustainability transitions. This not the least because the problems that transition theory has been concerned with, originate in practices that are transnational in nature (Grin 2013). Grin's ambition is to relate the multilevel perspective of transition theory to transnational governance in order to make a general theoretical contribution. The common denominator of transition theory is the multilevel perspective (Geels, Rip & Kemp, Schot) which conceives of transitions as the relationship between material, institutional and discursive processes at three levels: the landscape level representing exogenous factors and long term trends; the regime level representing institutionalised structures and established norms; and niches representing the level at which innovative

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[3] Annual Convention held in San Francisco, California April 3-6, 2013.

practices with transformative potential take place. The ambition of this paper is more limited as it mainly seeks to deepen our understanding about one level in the multilevel perspective, namely niches. That being said, it contributes with a suggestion as to how niches can be conceptualized in relation to transnational governance which includes the influence of such activities on more change-resistant levels as well.

In the research on the multilevel perspective, originally founded in the socio-technological systems studies, niches have mainly been associated with actors and networks engaged in technological innovations that promote environmental sustainability (Grin et al. 2011; Smith & Stirling 2010). Although, empirical studies to date have largely been confined to processes within nation states and particularly the Netherlands (Smith & Kern 2009) there is nothing in the theory itself that confines it within national borders. Quite the opposite, transition theory is informed by innovation studies emphasizing the transnational character of many socio-technological systems (see e.g. Hekkert et al 2007; Bergek et al 2008). Furthermore, the institutions, norms and structures that give rise to highly relevant unsustainable and greenhouse gas generating practices, such as in transport, energy, agricultural and industrial sectors, are practices that are transnational and global in their reach and related to long term trends like modernization and industrialization. In an article from 2010, Smith and his collegues say, about the analysis of transitions through the multilevel perspective, that "spatial scales in these transition processes has not been an explicit issue of concern" and suggest that such issues be considered not the least because of the empirical evidence of transition processes, not the least across regions and cities (Smith *et al.* 2010: 443).

Governance practices that attempt to regulate these flows are also of a transnational nature. What differs in the transnational context is that these flows are even more complex and fragmented than what has been shown in various national or subnational studies. To advance our understanding on these issues, Grin (2013) suggests that transition theory can learn from international regime theory and from multi-level governance research. The latter literature focus strictly on governance issues that is well-represented in EU studies but has developed independently from the multilevel perspective in innovation studies and transition theory. We take a starting point in these research fields to support the argument that states can be considered niches in the context of transnational governance, to develop this argument further by differentiating between different types of states. We suggest that forerunner-, pioneer- and norm-entrepreneur states can be conceptualized as niches in the transnational governance context. Lastly, we exemplify this with the case of Sweden in climate policy making.

Learning from multi-level governance and regime theory

The concept multi-level governance is used to describe governance in the EU as parallel governance processes, of states pooling sovereignty, of spill-over effects and of path dependencies (Kronsell 2012). It envisions governance, not as a top-down process but rather as multilevel bargaining where decisions are made through the weaving of strands of issues across territories, administrative levels and societal actors (Piattoni 2010), making the multilevel system an intertwined one with no given center of authority at any specific time (Bache and Flinders 2004; Hooghe and Marks 2001; van der Vleuten 2007; Walzenbach 2006) instead, in terms of governance, it appears as a system of heteroarchy (Neyer 2003: 689). Yet, it can be argued that national actors, either as governments, administrative networks or some combination of state and other actors, tend to come out as particularly influential in empirical work on multi-level governance, albeit, differentially located and embedded in complex patterns of governance relations.

Also regime theory in international relation, as Grin (2013) notes, supports the argument that transnational governance is complex. The often cited definition of international regimes is Stephen Krasner's (1983) who defined regimes as "principles, norms, rules, and decision making procedures around which actor expectations converge in a given issue-area". The argument of regime theorists is that the transnational system consists of principles, norms and rules that make states neither the sole nor the most important actors in transnational relations. Various transnational institutions, organizations and networks are part of the system giving it a complex interdependent character (Keohane & Nye 1977). It should be noted that not only institutional and material factors are important, the norm creating (Barnett & Finnmore 2004) and rule making function of regimes (Ostrom 1990) is also highlighted. Hence, there is affinity with what is argued in the multi-level governance literature. Regime theory too posits that transnational governance is heterogenous (Keohane & Victor 2011). Authority in the transnational is fragmented, fluid and shifting, often according to issue areas, around which expectations may converge (for example on free trade) or may not (for example on climate). A consequence of the tendency of transnational cooperation to have a single issue focus is that it leads to institutional complexity, fragmentation, overlaps and contradictions (Zelli 2011).

Despite the fragmentary, multilevel, dispersed authority of the transnational system or context there are some resemblances between regime theory and the multilevel perspective. To delineate this, Grin (2013) builds on work by Djelic and Sahlin-Andersson (2006) who argue that however fluid and fragmented the transnational system seems to be, at a deeper level it is structured and ordered. This also affects actors' practices. These more ordered elements that are both discursively construed, institutional and rule bound represent the 'landscape' and 'regimes' known in the multilevel perspective. The landscape and regimes are the result of aggregated effects of earlier practices. Such practices have been studied in research on international environmental regimes.

A particularly interesting piece is Oran Young's (2010: 1-22) on institutional dynamics. He understands institutional change as the result of the behavior of environmental regimes as complex systems. His explicit interest in regime change, is relevant to the topic of the paper and to transition theory. In the book, Young (2010: 9) proposes five different patterns of change: progressive development, punctuated equilibrium, arrested development, diversion and collapse. The patterns are derived from previous research and analyzed through case studies. It can be argued that the different patterns of change explored by Young, can contribute to the understanding of the transition process in relation to the transnational context. The patterns leave some room for agency, albeit limited, it is only the punctuated equilibrium that gives a clear space for agency, and then in certain moments only.[4] This is also discussed in transition theory. Avelino and Rotmans (2009:559) say that in transitions an important power dimension regards "the relation between 'regimes' and 'niches'. When the system is in a state of

[4] This was also noted by Grin (2013) in referring to Djelic and Sahlin-Andersson who had found a similar dynamic of opening up and closing down.

dynamic equilibrium, the regime has more power than niches." In this complexity and heterogeneity, it seems that 'windows of opportunity' are created. These are moments in which it becomes possible for niche actors to activate innovative power and influence the agenda, the regimes and, in turn, also the landscape. While regimes are vested with power as they are based on a specific distribution of resources, niches are able to exercise power through innovation (Avelino and Rotmans 2009:560).

A final take home point from the multi-level governance literature and (environmental) regime studies is that state actors continue to be important and relevant. It is less sure how, when and where states will and can act. When they actually can be influential is determined by 'opportunities' or openings in the regimes and landscape structures. On the question of which states are inclined to act and can be influential, regime theory posits that states assume different roles in the transnational system, for example as hegemons, as followers or perhaps as norm entrepreneurs (Finnemore and Sikkink 1998).

Niches in transnational governance

Now we return to the multilevel perspective and the concept of niches. Niches are a key feature and concept in the multilevel perspective. Niches represent agency and are thought as crucial for a transition to come about, and for instigating the change of social practices toward sustainability and low-carbon developments (Kemp et al., 2007a,b; Loorbach and Rotmans, 2006; Loorbach, 2010). As transition theory has developed and been applied in a range of contexts, empirical fields and for example in governance studies (Geels 2010; 2011a; Grin et al. 2010) the term niches has evolved to become more inclusive to a broader set of innovative actors and settings. For example, in transition management, niches apply to transition arenas, specific constellations of actors who not only have innovative ideas but are enthusiastic about pushing them forward in politics and governance (Foxon et al. 2009; Loorbach 2010; Schot & Geels 2008), i.e. actors in transition arenas are involved in a form of political struggle to change the agenda and turn it away from unsustainable governance practices. Most of the studies and conceptual work on niches has been within the 'transition management literature' with Derk Loorbach (2010) as an important scholar. To date, this literature has been strongly management oriented with a focus on the strategic activities of networks and individuals, who have innovative ideas, are enthusiastic and willing to pursue sustainable development issues. The importance of a type of reflexive thinking in innovative spaces, so called second-order reflexivity, is also accentuated (Voss & Bornemann 2011). Transition arenas have been studied fairly extensively in micro-politics and in terms of how they as niches, can contribute to regime change and transitions to sustainability and to climate objectives.

More recently, the concept niche has been applied to more areas. Cities and urban networks have been studied as niche actors within the context of the multilevel perspective of transition theory (Betsill & Bulkeley 2006; Bulkeley 2011; Geels 2011b; Hodson & Marvin 2010; Späth & Rohracher 2011). In his attempt to develop the transnational dimension of the multilevel perspective, Grin (2013) suggests that this research on cities can be a fruitful way to begin develop a transnational approach to the transition perspective. For example, Grin considers Hodson and Marvin's work (2010) as the first to explore the transnational perspective since they study how cities and urban networks can be innovative 'vertically' across transnational space.

While cities as niches may very well be one way to delineate a transnational governance perspective on transitions, it is equally interesting to highlight the important role that states can play in the transnational and global context. In this paper the suggestion is that it may be useful to learn from the multi-level governance and the regime literature and think about states or networks of state actors as niches. One reason is that state actors continue to have a strong political leverage in transnational governance (Jänicke 2006) and international relations and are, by many, considered highly important actors for furthering environmental and sustainability issues (Barry and Eckersley 2005; Bäckstrand et al. 2010; Eckersley 2004; Meadowcroft 2005, 2012). Another reason is that empirical research shows that specific states have pursued more active roles, by insisting on and pushing ahead toward environmental, climate goals and sustainability, in the EU and globally. Hence, it is useful to consider the concept of niche players in the transnational context in light of ideas about different states taking on and pursuing various roles in the transnational context.

States as pioneers and forerunners

Andersen and Liefferink (1997:2) investigated what they considered to be forerunner or pioneer countries in EU environmental policy: Sweden, Austria, Finland, Germany, the Netherlands and Denmark. These countries' forerunner status, they argue, "is connected to their historical role as catalysts in the EU policy-making process as well as in international environmental policy-making". Thus, they make a connection between the forerunners' EU activities and their activities in the global context. Here, the suggestion is that specific states – forerunners – can be viewed as 'niches' in the international system through their transnational activities. These forerunners act based on their previous experience with solutions and strategies often in the domestic or subnational context. Through this they have accumulated knowledge and expertise much sought after in the field of environmental policy-making both in other states and on the global arena. The transformative potential of pioneer states as niches, lies in the fact that they "seem to provide a stimulus to rethink established practices" i.e. they challenge the practices of current regimes and "cause changes in beliefs concerning what is feasible" (Andersen and Liefferink 1997: 4). The normative or norm creating capacity is accentuated. This normative dimension seems key also in transition theory as the "core process for transitions is a shift in belief systems" (Geels 2010: 499).

Forerunner or niche activities take place both in relation to the international institutions and transnationally, across states. For the EU, Andersen and Liefferink (1997: 5) stress that the influence of pioneers was "both 'horizontal' and 'vertical', by setting examples, the pioneers served as catalysts for the development of both domestic and international politics." Jänicke and Jakob (2006a) also argue the importance of pioneer states in setting common norms for environmental policy and strategies. Through globalization, pioneering countries have an arena for innovative environmental policy ideas but also for establishing lead markets for environmental innovations, i.e. global green markets (Jänicke and Jakob 2006a: 40). In a similar way transition theory posit that the innovations that emerge in niches combine social and technical elements (Smith et al. 2010: 441) and that "(n)iche-actors hope that their promising novelties" are used and eventually contribute to replace the regime (Geels 2011a: 27).

Hence, states' pioneering status includes both the normative aspects of policy diffusion and the development and diffusion of lead environmental innovations on the global market. Regarding policy innovations that are technologically based, Jänicke and Jakob write that "these pioneering countries often serve as regional starting points for new technologies" and open up new markets (Jänicke and Jakob 2006a: 41). The main point that comes across from their work is that while pioneer states facilitate environmental norm diffusion by advancing norms and policies, they also push technological innovations that might create new markets for more ecologically benign products or services. Thus, Jänicke and Jakob (2006a) stress the interconnection between normative and material/economic aspects of the forerunner role. It seems to be the interplay between technology and policy that makes the diffusion of environmental innovations and ideas possible. They are keen to point out the agency and influence of state actors. International organizations and the EU are important in this dynamic but their role is mainly to function as arenas where diffusion can take place as pioneers use them (Jänicke and Jakob 2006a: 46).

The pioneering states that have the capacity to act as niches for sustainability and decarbonization in the transnational context are according to Jänicke (2006: 58) states with highly developed economies, with high GNP and investments in research and development. They also possess the political and state capacity to carry strategies forward and as he explains: "This encompasses the institutional, economic and informational framework conditions and the relative strengths of the green advocacy coalition of a country" (Jänicke 2006: 51). Apart from actually wanting to pursue the role as forerunner, the picture of what it takes to pursue this role is multi-facetted. It is not only about the will of the forerunner state to pursue such a role in international and transnational arenas, it is also about the relationship and interaction between two or a set of states of which one is the forerunner. The success rate of a pioneering state is not only depending on its political, economic and institutional capacity but also based on a relational capacity. It is conditioned on the image that a specific state has acquired as being an innovator and forerunner (Jänicke and Jakob 2006a: 42; Jänicke 2006: 61). Thus, perceptions that other states have of the pioneer states is crucial for whether they will be listened to and their suggestions will be taken seriously.

The Scandinavians: forerunners with normative power

The importance of image for forerunner leadership is something which Gunnhildur Magnúsdóttir studied in her research (2009) on Sweden, Denmark and Finland's power resources in EU negotiations on environmental policy. Her investigation confirmed that these three states have all acted as leaders or forerunners in EU environmental issues and that this role was based on what has been discussed previously, their strong commitment to environmental policy and innovation in the domestic context through which they were able to set an example. She argues that in order to make use of examples, norms and knowledge as a way to be persuasive in policy negotiation, the image or reputation that this state has as a norm setter is an important resource, she calls it "a door-opening power resource" (Magnúsdóttir 2009: 238). Furthermore, she studied the link between the image that a forerunner state has internationally and the self-image of this state and found that there was a reinforcing or strengthening relationship between them. About this she writes:

> "A strong self-image derived from the state's activities and views on domestic ground, such as domestic environmental protection, can be seen as a solid starting point for the formation of a strong international image. A strong self-image creates confidence and can encourage the state in question to act as a unilateral leader or directional leader outside its national border, extending to the global arena, which enhances the state's international image. A favourable international image can in turn boost a state's confidence and self-image and then a circle is created where self-image and international image reinforce one another"
> (Magnúsdóttir 2009: 239).

The image and reputation of being a forerunner in environmental policy is a normative type of leadership (Ingebritsen et al. 2006) with an innovative power that creates new resources (Avelino and Rotmans 2009: 560). It is more suitable to the role that smaller states have in transnational and international relations (Jänicke 2006: 62). Indeed, Christine Ingebritsen (2002) defines Scandinavian countries as states with a distinct role as norm-setters in the international context. According to her, the Scandinavian countries are norm entrepreneurs who consistently provide ideas and policies. This norm entrepreneurship is a general characteristic of Scandinavian countries and not restricted to environmental and sustainability issues. It also includes conflict resolution, gender equality and models of global aid giving. Christine Ingebritsen (2006: 5-10) argues that Scandinavia's role is both *objective*, in the content of foreign policies and actions based in a long tradition of ecological institutionalism (Ingebritsen 2012), and *subjective* in that it is about how others view these countries. She suggests: "Ideational leadership and transnational activism continue to be defining features of Scandinavian foreign policy making" (Ingebritsen 2006: 11) and that this leadership and norm entrepreneurship is particularly prevalent in environmental and sustainability issues (Ingebritsen 2010).

Sweden as a niche in transnational climate governance

A way to evaluate the role as niche in the transnational context is to investigate the activities of the forerunners, pioneers, or norm entrepreneurs in the context of transnational governance. Many studies attest to the prominent role played by Scandinavian countries, and particularly Sweden, in promoting environmental issues in the international context. For Sweden this is a practice that dates back as far as the first UN conference on the Environment held in Stockholm 1972 (Kronsell 2002; Magnusdóttír 2009). Magnusdóttír (2009) writes that Sweden has had such a leadership function in EU environmental policy, and that it is based on behaviors in the past which has given Sweden an international image as forerunner in international relations. The international image has been reinforced by Sweden's own self-image.

In previous research Kronsell showed that Sweden has actively pursued a position as forerunner and example setter when it comes to environmental issues in different contexts, in relation to the international context (Kronsell 1997), transnationally and in the EU (Kronsell 1999; 2001; 2002; 2004). This appears to be the stance also when we look more specifically at climate issues. Sweden has pursued this role in international scientific cooperation on climate issues (Knaggård 2013). The forerunner ambition is articulated in the 2009 Climate Bill and was confirmed by the then Environmental minister Andreas Carlgren when he launched what was to become a large effort at climate governance within Sweden, the low-carbon roadmap for 2050. In an article in Sweden's major newspaper he says:

> "Some countries have to be frontrunners and show that it is possible to lower emissions while at the same time create the conditions for a good life. Sweden should be a country which pulls other countries along in the development toward a green economy and a green future" (DN July 21, 2011).

In climate issues Sweden's role is to be a forerunner as a way to pull other industrialized countries to go forward with their commitments. According to Mathias Zannakis (2010: 236) this behavior cannot be explained by self-interest but is related to an idea of what he calls "ecological justice" which points out the responsibility of industrialized countries for climate change. Zannakis (2010: 18) even calls Sweden's behavior in climate issues as highly paradoxical:

> "The paradox of Sweden's behavior is that the country has probably contributed most of all countries in the climate change issue, in relation to its international commitments and GHG emissions per capita. Sweden is unique in that the country will over-implement its international commitments, while already having among the lowest per capita GHG emissions in the industrialised world."

This pursuit of 'ecological justice' is coupled with an idea about 'opportunities'. Much in the way that has been argued by Jänicke and Jakob (2006), Zannakis says that for Sweden, taking the lead toward the carbon-free society also implies opportunities in ecological innovations (Zannakis 2010: 237).

So far it is possible to conclude that Sweden has this international image as a forerunner in environmental issues, which also seems to apply in the context of climate issues, at least when self-image is based on what is articulated in official documents. To study forerunner strategies or niches in terms of their success does not offer easy explanations with strict causalities. The transnational context is as both international regime theory and the multilevel governance approach suggests, highly complex. This should not discourage researchers from trying to establish how niche actors work, with which strategies, and with what ideas, norms, practices and experiments they act.

National climate policy-makers' views on Sweden as niche

A way to assess self-image is to study how key policy makers view Sweden's role. This is also the approach Magnusdóttír (2009) used when she analyzed self-image. Her study surveyed environmental policy making in the EU. The material we used was derived from interviews with 59 key policy makers in the climate issue area at the national level (reported in Kronsell *et al.* 2011). A question about success factors in Swedish climate policy-making was posed in the interviews but there were no explicit questions about forerunners raised.

The answers did confirm in general terms what has been argued earlier, that Sweden is a niche actor in climate issues. Some policy makers expressed it as follows: "Sweden is better than many industrialized countries, there is no doubt about that. We don't use coal or gas, or burn oil to heat our houses. We must admit progress has been made." and another voice: "I must say that our climate politics has been a success and that Sweden is a forerunner in this respect. The clearest sign of this is the decoupling of emissions from economic growth." Another policy maker also suggest that decoupling is an important example and continues on this theme: "… this is an example of success, and in EU cooperation this Swedish example, that we have managed continued economic growth while lowering emission levels, is often brought up."

In regard to being a niche actor, policy-makers suggest that the possibility to pursue it is based on experience in the domestic context. "It feels like we have got quite far, these [climate] issues are difficult but we have gone through these things over many years and it seems as we now have experience as to what works or not." This is much in line with what has been argued in the forerunner literature (Andersen and Liefferink 1997) that niches accumulate expertise through experiences with strategies in the domestic context.

When evaluating the entire interview material and the answer on this particular question it was possible to establish success factors. The most important factors for success were also considered an important base for Sweden's role as a niche actor in Europe and internationally: a) the CO_2 tax, b) the general consensus on climate issues and c) the experience with environmental policy-making in the past.

The CO_2 tax is viewed as an "extremely important piece of the puzzle which has led Sweden away from a fossil fuel dependence". The early start in using economic instruments "like the CO_2-tax is an example that more and more countries are also following." The policy-makers also explain why the CO_2 tax has become the most successful initiative. "It was introduced in 1990 and has changed over time, but it is the long-term stability of this instrument, once it was established, that has led to more emission reductions than we expected to accomplish." Another policy-maker insists on "the benefit of a long-term and stable commitment to the CO_2 tax which has had an enormous effect" and that "this pressure for change in a fairly specific direction over a long time has been an important signal to the market." Yet, another speaks about the effects of the CO_2 on the energy sector. "We see an enormous change in the electricity and district heating sector. For example, in the housing sector we have moved from individual housing units having their own heating solutions to an extensive developed district heating with bioenergy as the major fuel source, not coal."

In the interviews the policy maker referred to what Jakob and Jänicke (2006) argued about niche actors, that their forerunner activities in the field of policy also gives benefits on the market. In one interview we heard that: There are many researchers, small and midsize businesses who are happy that Sweden "has a history of strong environmental policy and acts as a forerunner" and the respondent explains: "a shift has occurred and more and more people realize the importance of creating a market." It is beneficial "that since way back, Sweden has an international reputation of being in the forefront on environmental technologies. Swedish businesses can now benefit from this."

The other success factor that came across in the interviews was the general climate consensus in Sweden and confirms what Zannakis (2010) concluded from his study on climate discourses in Sweden referred to earlier. Among politicians, policy-makers, industrial actors, non-governmental organizations, the scientific community there is a general consensus that the climate issue is important and urgent to deal with and this is coupled with a high level of awareness of what the climate implications may be. This broad support, the policy makers argued, means that in Sweden there is a consensual platform about the climate problem; what caused it, how it could and should be dealt with. This consensus also involves the public: "We have a climate conscious public" because "in Sweden people in general are highly educated and the public is accepting new thoughts and ideas." This is viewed as beneficial to, for instance, pursuing the transition to a low-carbon society. This broad consensus has been important also for the possibility to push climate issues on the political agenda. There "has been political pressure to pursue an active climate agenda." The political commitment has been important to give courage to politicians to pursue new and stricter steering instruments for climate objectives.

The experience of having pursued and established a strong environmental policy tradition early, is the third aspect that the policy makers brought up among important success factors for the Swedish climate policy agenda. Some also pointed out that these factors are connected and reinforce one another, and they also relate to the role as niche actor: "with an international comparison there are many successes. Sweden is a forerunner when it comes to governing climate issues and in actual emission reduction. Politicians have dared to push strict policies and we have a climate aware public. These things are connected…". In the interviews, one respondent referred explicitly to the connection between the national and international level, suggesting as Magnusdóttír (2009) does in her research on the Nordic countries in EU's environmental policy, that there is a reinforcing dynamic between self-image and international reputation that is important in the pursuit of a forerunner role. The respondent talks about how it has been crucial that "a lot of energy was devoted to environmental issues early on" because this, in turn "encouraged the establishment of environmental organizations that were able to develop a strong lobby" which could keep up the pressure. Simultaneously, the activities of "Swedish politicians and scientists pursuing new environmental ideas in international organizations were a point of reference which made it much easier to continue the work in the domestic context." Martin Jänicke (2006) also speaks about this in that a forerunner needs to have economic and institutional capacities as well as strong green advocacy.

Finally, it is important to point out that in our material there are some policy-makers who express a more doubtful view about Sweden as a niche actor. Two policy makers were openly skeptical and doubted that Sweden had ever been a niche actor: "I wouldn't say that our climate policy making is better than England for example" or "that it is more progressive and ambitious than other countries". They go on to argue that "the success for example of the CO2 tax was more of lucky strike than a conscious policy decision..." considering that its introduction was timed with the need for a tax reform that comprehensively restructured the income taxation in the beginning of the 1990s.

A more common position among policy makers is that they seem to agree with the idea that Sweden has been a forerunner but suggest that climate policy making is no longer as much in the forefront as previously: "It feels like we were more forward before…you don't even hear the rhetoric that a strong climate agenda will give us an advantage on the market. This was the case previously, when they even put government commissions to investigate this topic." Another respondent says that "the ambitions that Sweden should be way ahead has become looser, now in practice, it is more about being among those in the forefront and not necessarily at 'the forefront'."

Yet, another policy-maker delivers an explanation why we see stagnating ambitions in current climate politics. It seems to be about politics with a split in the different sectors of the government and administration. "The different ministries have a different position on this [Sweden as forerunner]. The Environmental ministry wants to still be best in class while if you listen to what the government says this is relaxed and the emphasis is on evaluating the costs." S/he continues to argue that an ever increasing part of the climate agenda and the important measures "like the taxes, are under the jurisdiction of the finance ministry and the thinking that prevails in the finance ministry." In the finance ministry "the concern is about leveling differences between sectors and between us and the global arena. The utility of being in the forefront is questioned, while the idea is that Sweden should continue to be a force that pushes, there is no need to be way ahead of others." That definitely breaks with the previous Swedish approach of being a forerunner at home and an activist state internationally.

Concluding remarks

The ambition of this paper was to elaborate how niches can be conceptualized in relation to transnational governance. It uses multi-level governance theory and international regime theory to argue the complexity of the transnational context where states still remain important actors. The argument about states as niches was then developed by turning to studies that differentiate between types of states. Forerunner-, pioneer- and norm-entrepreneur states can be conceptualized as niches in the transnational governance context. This was exemplified with the case of Scandinavian countries in environmental policy and went on to investigate whether Sweden can be viewed as a niche in transnational governance of climate issues and did this by analyzing policy-makers' view of climate governance. There seems to be a fairly strong held belief that Sweden has this role, which was particularly related to the successful use and implementation of the CO_2 tax. Another important factor for the niche actor according to policy-makers was the broad political and societal consensus on the importance and relevance of the climate agenda. However, there were also indications that the consensus is crackling at the political level, which may suggest that Sweden's role as a niche in transnational governance may be dwindling. Thereby, it can confirm the view that niches can become successful and bring about transitions at certain moments when there are windows of opportunity, hence, the role of niche state in transnational governance is not a permanent or lasting condition but a moment. Yet, the grounds for becoming a forerunner in climate politics is about dedication and persistence in pursuing policy measures and creating a broad consensus at home while obtaining trust for this in the transnational context. These processes are built up over a long period of time.

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Transformation towards sustainable consumption: Changing consumption patterns through meaning in social practices

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Introduction

Against the background of environmental problems arising from the growing extraction of natural resources and resource depletion, achieving a sustainable development is an indispensable challenge in the twenty-first century. As Rockström et al. (2009) show the current ecological impact, caused by economic action, is already exceeding the ecosystem's capabilities to compensate for interventions in some areas. However, projections of current economic and human development still show that without radical changes the use of natural resources will even increase in the next decades. Bringezu and Bleischwitz (2009) i.e. predict that the global extraction of raw materials might double or triple until 2030, if western consumption patterns are also adopted in now developing countries. To reach sustainable development societal transformation (WBGU 2011) as a whole towards sustainable patterns of production and consumption is required, most urgently in the fields of living, mobility and food (Acosta-Fernandez 2012). Transition research (i.e. Geels and Schot 2007; Spaargaren et al. 2006) has recently gained much attention as a theoretical framework and blueprint for empirical work on sustainable development. Transition is thereby understood as a "radical, structural change of a societal (sub)system that is the result of a co-evolution of economic, cultural, technological, ecological and institutional developments at different scale-levels" (Rotmans and Loorbach 2010). The multi-level perspective (MLP) on transitions of socio-technical systems as an interplay between socio-technical regimes, niches and landscapes is in the centre of this approach.

Often, the scientific and political debate concentrates on technological innovation to achieve more sustainable development, i.e. by improving resource and energy efficiency, enabling future markets in green growth economy. Economic action of humanity might, thus, be brought back to ecologically acceptable limits within a „safe economic operating space" (Rockström et al. 2009). Concepts to reach a dematerialization by a factor 10 (Schmidt-Bleek 1993) are necessary to stay within the environmental space (Spangenberg 2002; Opschor and Constanza 1995). Environmental space refers to the amount of resources we can use without comprising future generations' access. Doubtless technological innovations are an important pillar of sustainability transitions. However, rebound effects of efficiency gains (Sorell 2007; Druckman et al. 2011) or wrong application of potentially sustainable innovations (Liedtke et al. 2012) show the limits of the presently anticipated technology oriented strategy to cope with sustainable development (Liedtke et al. 2013a).

The concept of transition already offers a broader perspective by embracing cultural and institutional change. In this paper, we therefore argue for a coupling of resource efficiency strategies with social innovations (Howaldt and Schwarz 2010) in the sense of reconfiguring established social practices towards sustainable patterns of action (i.e. sufficiency strategies, Stengel 2011). Social innovation, for the context of our paper, means a reconfiguration of social practices involving consumption of some kind towards a lower level of consumption, re-use/ longer use or design and implementation of low resources product-service-systems.

We hypothesise that a change of social practices, as routine patterns of action, plays a crucial role in transition processes. An important field is the transition of current (mainly western) consumption (and production) patterns (Jackson 2005; Røpke 2009; Spangenberg and Lorek 2002; Baedeker et al. 2009; Liedtke et al. 2013a; Schneidewind and Palzkill 2011; Stengel 2011). Only employing sustainability strategies which address integrative efficiency, consistency and sufficiency (Schmidt-Bleek and Tischner 1995; Liedtke et al. 2013b) can lead to an absolute decoupling (Jackson 2008; Schmidt-Bleek 1994; von Weizsäcker 2009) of resource use from the increase of societal well-being.

We propose an integrative theoretical framework of sustainable consumption and production (SCP) to guide transdisciplinary action research processes towards sustainable transition. This model aims to both inform empirical research and to design change processes to support practical transition. The model is based on the experience of many years of research by the members of the Research Group "Sustainable Production and Consumption" at the Wuppertal Institute and on a review of important theories of consumption behaviour (i.e. Jackson 2005; Defila et al. 2011). For the purpose of this paper, we concentrate on introducing the theoretical framework and discussing one key aspect to support change of consumption patterns – the element of interpretative patterns and meanings in social practices. Using the examples of smoking and car driving, Stengel (2011; 2013) has shown how change of interpretative patterns, associated with the consumption of goods, can help to overcome an important barrier to more sufficient lifestyles. The framework links the MLP of transition research and theories of practices, as it has recently been proposed (i.e. Watson 2012; McMeekin and Southerton 2012).

The argument for this link is twofold: 1) Regimes and transition can usefully be explained more informatively using practice theories and 2) as Warde (2005) points out, consumption is an element in many social practices involves consumption (Warde 2005). Social practices are the appropriate level of transition analysis also because research shows that for many products, the use phase (users' social practices) is most relevant for its environmental impact, i.e. clothing (Paulitisch and Rohn 2004) or heating/space heating (Liedtke et al. 2012). Private households can directly or indirectly influence part of the environmental impact through their consumption patterns in many of these fields (Spangenberg and Lorek 2002) and ways of usage.

The following underlying research questions are addressed: How can efficiency, sufficiency and consistency be increased by transforming social practices step by step towards more sustainable patterns of action? How can people be empowered to design their own lifestyle in a limited environmental space, so that they are able to manage their material footprint with creativity and fun? How can social innovation be used as a driver for needs oriented socio-technical interaction and design of more sustainable PSS? How should socio-technical systems be structurally adapted to support this process of social innovation so as to reinforce each other? And how can a transition process be multiplied based on cultural behaviour patterns of the broader society – coming from niche actions to mainstream?

Our paper is structured as follows. We begin by introducing the norm-activation model (Matthies 2005) and discuss practice theories on consumption behaviour. Production and consumption form an integrated value added system; transition, thus, needs to address both as permanently influencing each other. We then briefly discuss the sustainable transition research approach. Based on a review of strengths and limitations of these individual approaches, we outline an integrated theoretical framework which puts the transformation of social practices in socio-technical regimes (as social innovation) on centre stage in achieving sustainable patterns of consumption (and, step by step, of production). Identifying social practices as a key dimension of analysis, we then look at methods to support change of practices and, via the spread of social innovation, achieve transition. In our historical case reviews we concentrate on the central role of *meanings* in social practices.

1. Theoretical background of consumption patterns

Based on a review of common theories on consumption (cf. i.e. Jackson 2005; Defila et al. 2011; European Commission 2012) and on many experiences from the work of past years at the Wuppertal Institute[1], we concentrate on aspects of the following theoretical approaches to integrate them into our framework: the psychological norm-activation model (Matthies 2005), economic theories of rational choice, social practice theories of consumption and structuration theory (Giddens 1984).

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[1] The research group "Sustainable Production and Consumption" designed its research strategy along the mission of the Wuppertal Institute. The focus is on the assessment of resource use potentials, i.e. sustainability indicators of technologies, value chains, companies, households and on the analysis of patterns of action in value chains, considering the multi-level system. Along this research focus, a graduate programme is developed, which supports the theoretical foundation of our research. Pilot projects support the graduate programme and enable social-empirical research and physical analysis as well as the development of scenarios and action research methods to accompany practical transitions. For the transfer and diffusion to science, economy and society appropriate methods of communication and didactics are developed. The graduate programme addressed these questions:

- How to design political conditions and instruments to support change processes towards resource efficiency? (Kristof 2010; Onischka 2010)
- Which are driving factors for a change of interpretative patterns? (Stengel 2011; Kristof 2010; Lukas, in process)
- How can communication strategies be designed for specific target groups? (Lubjuhn 2011; Seibt 2013; Nordmann, in process)
- What can regional and value chain spanning networks contribute to change processes? (Baedeker 2012; Geibler 2011; Hasselkuß, in process).
- Which rebound effects arise at which spots in the multi-level system? How can sustainable patterns of action be developed by the actors themselves? (Buhl in process; Lukas in process).
- Which skills and competencies need to be developed to design complex change processes? Which barriers exist, which success factors? (Baedeker 2012, Geibler 2011)
- Social practices and transformational design (Laschke in process)

Results are taken into account for development of the SCP Transformation Model and evaluated in the respective pilot projects (i.e. SusLabNWE (http://www.suslabnwe.eu/), Holzwende 2020plus: Sustainable Future Markets for Constructing with Wood (www.holzwende2020.de), Return & Recycling of Used Mobile Phones (http://wupperinst.org/en/projects/details/wi/p/s/pd/388), Material Efficiency and Resource Conservation (http://ressourcen.wupperinst.org), Education for Ressource Conservation and –efficiency (www.bilress.de))

1.1 Social Practice Theories in Consumption Research

In recent years, **theories of social practices** have gained a lot of attention in the analysis of consumption (i.e. Reckwitz 2002; Warde 2005; Røpke 2009; Brand 2010; Shove et al. 2012). Most prominent, these have been applied when consumption – and the related environmental impact – is conceptualised to mainly result from consumers' routines. The body of these theories has emerged from sociological theories i.e. by Bourdieu (1977), Giddens (1984) and Schatzki (1996), who all worked on practices as a central category of social analysis. Reckwitz later (2002) aimed to provide a cohesive theory of practice as a sociological approach on its own. As one of the baselines, social practice theories draw on the idea of duality of structure, as proposed by Giddens (1984). In many theories, social structures are an entity of their own, guiding or even determining individual actions (i.e. systems theory). On the other hand, sociological theories of action tend to overemphasize the influence of individual interpretation and agency, thus, leaving out the guiding function of structures. Criticising both, Giddens introduced his theory of structuration as an attempt to overcome the micro-macro-dualism in sociology. According to this framework, actors are knowledgeable and reflexive, both enabled and constrained by social structure (as virtual sets of rules and resources) in their actions, while structure at the same time is only (re)produced by actions. Structure consists of rules (of legitimation and signification) and of resources, subdivided into allocative resources (i.e. financial means, technology) and authoritative resources (as a source of power over other actors). Giddens also differentiates the side of action by employing a model of action, where, actors remember rules as memory traces on different levels of consciousness.

Structures are then (re)produced in a recursive process through (mostly routinised) social practices. In situated social practices (appropriate rules and resources for a given situation are identified by context), actors draw on these sets of rules and resources; at the same time these only exist as long as actions keep them 'alive'. Reckwitz (2002) accordingly identifies social practices as the location of the social, where action and structure are mediated. He defines practices as "a routinised type of behaviour which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, 'things', and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (Reckwitz 2002, 249). All activities can be considered a practice from this perspective. Actors need specific skills, largely implicit knowledge, and control both over their bodies and over material artefacts (meaning all sorts of technology devices). In Giddens' terms, for routine practices actors largely draw on the practical consciousness; meanings and legitimation associated with a practice are usually not reflected. Yet, practices are not always enacted in exactly the same way but actions can vary.

Warde (2005) showed that consumption is not a practice itself but rather engaging in many practices, which requires a certain level of consumption of goods or services. This also means that consumption of many goods and services and the according resource consumption result from non-reflexive, routine enactment of practices rather than from individual desires. Looking at the kind of image of humanity behind theories of practices one could say that actors are conceptualised as well capable of reflexive action (they are knowledgeable and capable to even consciously act against social norms), yet in everyday life non-reflexive routines dominate and are necessary due to the complexity of modern world.

For Shove et al. (2012) practices consist of the elements *images*, *skills* and *stuff*. This threefold image simplifies the complex idea behind the concept of practices; still it is associated to the elements discussed above: 'images' relate to interpretative rules, 'skills' to what Reckwitz shows actors need to know and 'stuff' to the material aspect. Styles of consumption are interwoven with social practices of certain activities but also with daily routines i.e. in households (Brand 2010). Consumers, then, combine a number of different practices related to nutrition, mobility etc. and form them into *lifestyles* (Spaargaren 2003; 2011).

The **strengths** of this approach lie in overcoming the micro-macro dualism of explaining consumption behaviour. Furthermore, Giddens' structuration theory is already an element of the MLP in transition research and practice theories can be linked to the MLP (cf. i.e. Watson 2012; McMeekin and Southerton 2012). The approach is **limited** in that at first sight it focuses routines and social reproduction and not change. Newer theories of practices have shown ways to overcome this limitation (i.e. Shove et al. 2012; Watson 2012), still it is problematic to explain when or under which circumstances actors are more likely to deviate from routine practices. As Shove et al. (2012) and Watson (2012) discuss, practices can change through a change of their elements, a change of population (the practioners) or by changing the interrelation or links between different practices.

1.2 The Norm-Activation Model

Because of its attempt to link psychological and social factors influencing consumption behaviour, the modified **norm-activation model** by Matthies (2005) is a very interesting approach for the purpose of an integrative model of SCP. While many psychological models focus solely on the individual's attitudes, emotions etc., the norm-activation model offers links to social influence, as we will show in the following paragraph. In her model, Matthies differentiates between four phases of deciding and acting environmentally equitable or to stick to habits and eventually act environmentally harmful. The following figure shows these phases.

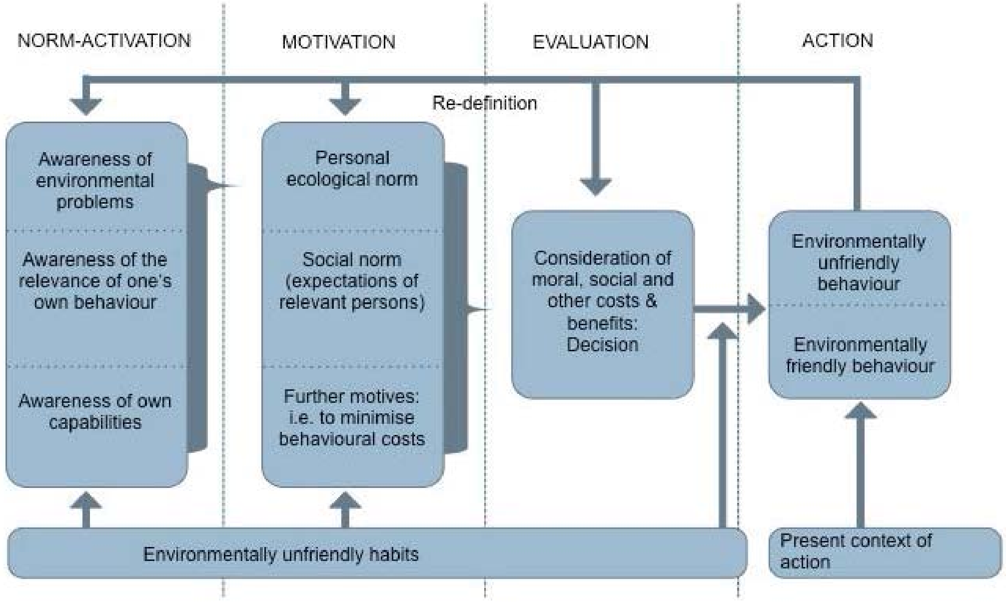

Figure 1: The norm-activation model by Matthies (2005); own depiction based on Matthies

A person activates ecological norms during the phase „norm-activation“, when she/he is aware of environmental problems and of the relevance of her/his own behaviour as well as of her/his own competences to address environmental problems. As such, it is mainly concerned with knowledge and reflexive thinking. The „motivation“ phase is influenced by *personal* ecological and *social* norms, framed as expectations of important persons. Based on this, a person would evaluate the different motives and norms, weighing up benefits and costs – mainly based on moral and social costs rather than prices and budgets. At this point the model argues in terms of rational choice.

The **strengths** of this approach can be seen in the conceptualisation of decisions for or against resource protective behaviour and taking up habitual constraints – in thus far it opens the black box in social practice theory concerning when a routine practice is more likely to be left by individual actors. Matthies concentrates on re-definition as repelling feelings of guilt but through this aspect the model is also a reflexive approach. The re-definition loop also might be seen as a potential for experiential learning. This opens connecting points for different approaches to change social practices. The specific **limitations** of this approach lie in its individualistic perspective. Social rules are only considered as expectations of relevant others – this needs to be connected to the social macro-level, as structuration theory can offer. The important rules of signification (and respective modalities) as shared interpretations are not considered by Matthies. Also, resources are not considered, however, these are key to deep changes, since they enable the transformation of new patterns of action into social structure and vice versa. The missing macro link also limits insights at the systems level.

1.3 Coleman's model of social change

Coleman is one of the most important sociological theorists of rational choice. Based on his assumptions on the logic of collective action, he introduced a model of social change which explains macro dynamics as an aggregation of individual choice (Coleman 1991). Explaining social macro factor y from macro factor x would only be possible by analysing the constraints of x on individual rational choice. Under these given restrictions rational choices of individuals would collectively lead to a new state of macro factors (y). Coleman's **"bathtub" model of change**, exemplified for explaining revolutions, is shown below.

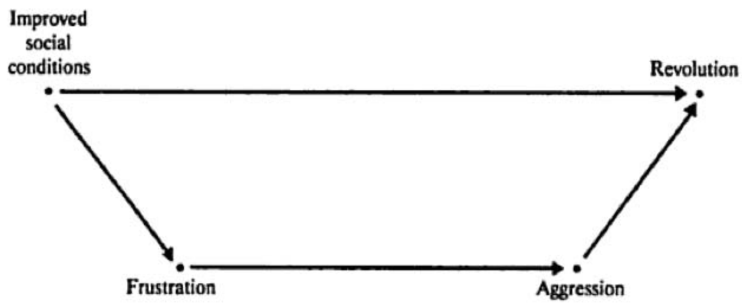

Figure 2: Coleman's "bathtub" model of social change (Coleman 1990, 10)

Liedtke et al. (2010) have adopted this model and extended C with the norm-activation model. Successful ecological norm-activation would then lead to individual rational choices in favour of environmentally protective behaviour and, thus, to a sustainable society in the aggregate – supported by communication strategies or education. The underlying idea of aggregation seems adaptable to the diffusion of social practices and is connected to our SCP Transformation model, as we will discuss below.

2. The Transition Research Approach

The transition research approach (i.e. Geels 2004; Geels and Schot 2007) was developed in the Netherlands and has recently gained influence because of its ability to theoretically frame complex change processes, such as required by the challenge of sustainable development, and guide empirical research. It aims to identify underlying patterns and dynamics (Geels and Schot 2007). In the centre of the approach stands the MLP, which describes transition on the regime level of socio-technical systems (system innovation) as an interplay of the functional levels of socio-technical landscape, regime and innovative niches, as shown in Figure 3. *Socio-technical* r*egime* refers to the dynamically stable interrelation of markets, culture, science, technology, industry and policies around one socio-technical system (i.e. that of (auto) mobility). Economic activities and paradigms are part of human social and political systems. These systems are not only developed on material framework conditions but also on culturally formed images and mental structures, e.g. norms and values. Transformation towards more sustainable social and economic structures is not an easy task. It is a complex process characterized by so-called lock-in effects. Lock-in effects are the result of the interplay of multifaceted factors and may refer to infrastructures, technologies, institutions and the closely connected areas of production processes and consumption patterns (Arnold 2007). The *socio-technical landscape* refers to dynamics at a higher level of abstraction such as societal cultural shifts or climate change which cannot be influenced directly by actors in the system. Innovative niches are complementary to regimes as a kind of innovation laboratory in which i.e. new sustainable technologies or social innovations are developed but not yet largely implemented.

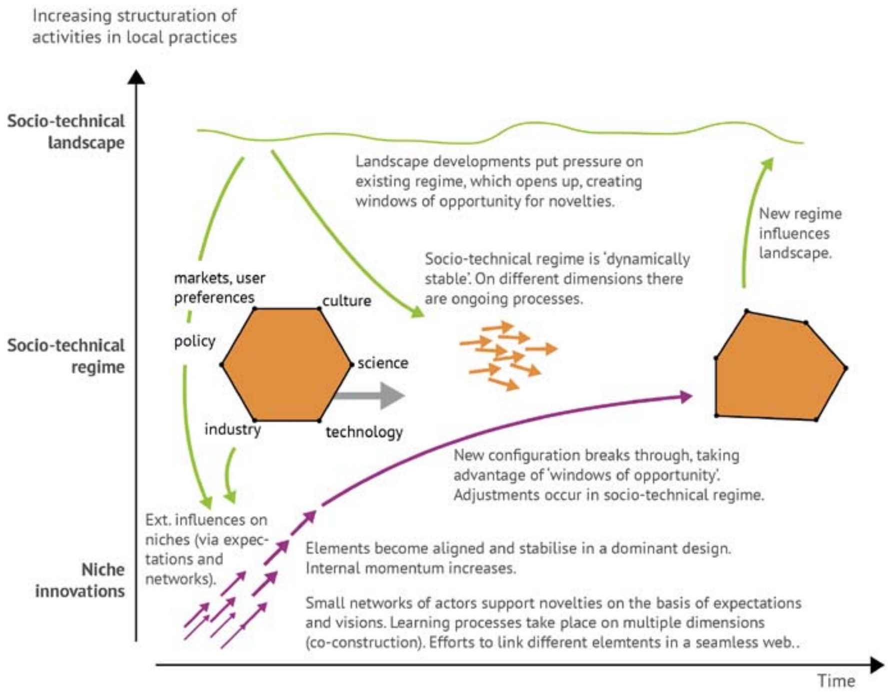

Figure 3: The multi-level perspective in transition research (based on Geels 2011)

Geels and Schot (2007) differentiated four transition pathways, among which *technological substitution* and *de-alignment and re-alignment* appear most important for our model. For the purpose of this paper, we dispense a further in-depth review of the transition approach.

To describe and manage complex processes of change the transition management cycle was developed, which distinguishes the phases of Problem Assessment, Vision Development, Experiments and Learning & Upscaling (Loorbach 2010). At the Wuppertal Institute transition research is established as a meta-approach for the institute's research and development in sustainability (Schneidewind et al. 2011).

The **strengths** of the MLP can be seen in analysing dynamics between the different levels and the time-reference in change processes. It shows in how far the different levels are permeable for innovation processes and integrates effects on structures in regimes. Geels (2011) shows that despite of criticisms towards the MLP, agency is considered by transition research. Yet, the integration of individual restrictions and routines of actors in socio-technical systems is **limited** but are very important for understanding the diffusion of (social) innovations from niches to adjustments in regimes.

3. An integrated theoretical framework: The SCP Transformation Model

3.1 Theoretical integration: Linking MLP and social practice theory

In this chapter, we outline our theoretical framework building on the individual approaches discussed above. We argue that a social innovation perspective, understood as spreading intentionally reconfigured social practices, can help to conceptualise transition on the regime level. Both theories of practices and the norm-activation model have strengths and limitations. By integrating them it becomes possible to overcome some of these limitations.

The hypothesis is that not only the often discussed knowledge-action-gap constrains sustainable consumption and production practices. Much more there is a lack of connection between sustainable practice novelties and broadly accepted and collectively shared rules and resources.

First it should be clarified how a dynamically stable socio-technical regime is understood from a practice theory perspective. As introduced above, the MLP already draws on Giddens' structuration theory. According to Geels (2004; 2011), 'regime' constitutes the deep structure of a socio-technical system, in which a set of rules is established, mostly characterized by lock-in. Rules were the medium and outcome of action, just as Giddens puts the concept of duality of structure. Geels names cognitive routines and shared beliefs (interpretative rules according to Giddens), capabilities and competences, lifestyles and user practices, favourable institutional arrangements and legal contracts as examples. Practices in niches are characterised by a low level of structuration and, thus, institutionalisation compared to regime practices, whereas landscape practices are very highly structured.

Following the discussion of theoretical approaches above, we take this aspect as very promising and concentrate our analysis on lifestyles and user practices. In line with Watson (2012), we argue that regimes in a specific field of action can be seen as a set of specifically interrelated practices, which are routinely reproduced by actors and, thus, are considered to be institutionalised. To him, „...practices (and therefore what people do) are partly constituted by the socio-technical systems of which they are a part; and those socio-technical systems are constituted and sustained by the continued performance of the practices which comprise them“ (Watson 2012, 2). Together with practices, the corresponding sets of rules and resources (the meanings, norms competencies, infrastructures and artefacts) are institutionalised through their (re)production by actors performing social practices[2]. A socio-technical system (i.e. (auto)mobility) then encompasses interdependent technologies, infrastructures, markets and meanings (cars, car-drivers, roads, petroleum supplies etc.), as Watson points out based on Urry (2004). Regimes should however be seen as "systems of practice" (Watson 2012, 7). According to Geels (2011), the MLP has been criticised for its hierarchical notion. We do not share this critique but instead take up the idea of a rising level of structuration of local practices. Having said this it becomes clear how deeply important social practices and agency (as practices need to be enacted) are to

[2] This notion of practice corresponds to the practice-as-entity reading as opposed to practice-as-performance, meaning the concrete enactment by actors (cf. Watson 2012).

understand transition, while at the same time in no way neglecting the importance of technical innovation: „Any socio-technical transition has to be a transition in *practices*“ (Watson 2012, 2).
Spaargaren et al. (2006) also suggested to view transition in terms of Practice Theory as a circumscribed process or trajectories of change within the time-space bound reproduction of social practices. Above, we introduced that practice theories show how consumers can combine engaging in different practices (many of which include consumption of some kind) to individual lifestyles (Spaargaren 2003; 2011) – this stresses agency and the reflexive project of self (Giddens 1991). Now it should be remarked that perhaps foremost the interrelatedness of structured practices in everyday life (constituting a regime) also constrains individual choice and partly preshapes how actions can be performed (as Giddens puts it, structure is both constraining and enabling, i.e. by providing stability).
The MLP can correspond to this idea of more and more interrelated practices (across time and space). On the landscape level, so many different practices, performed by actors across various time and space scales, interrelate in such a way that human action becomes almost invisible – cf. proving climate change is caused by human action. Thus, regime practices are relatively stable and it needs to be analysed under which circumstances actors leave such practices.

Example: Practices of bathing

In the example of bathing practices it becomes visible why social practices of how actors use technical artefacts is most relevant for the study of sustainability transitions.

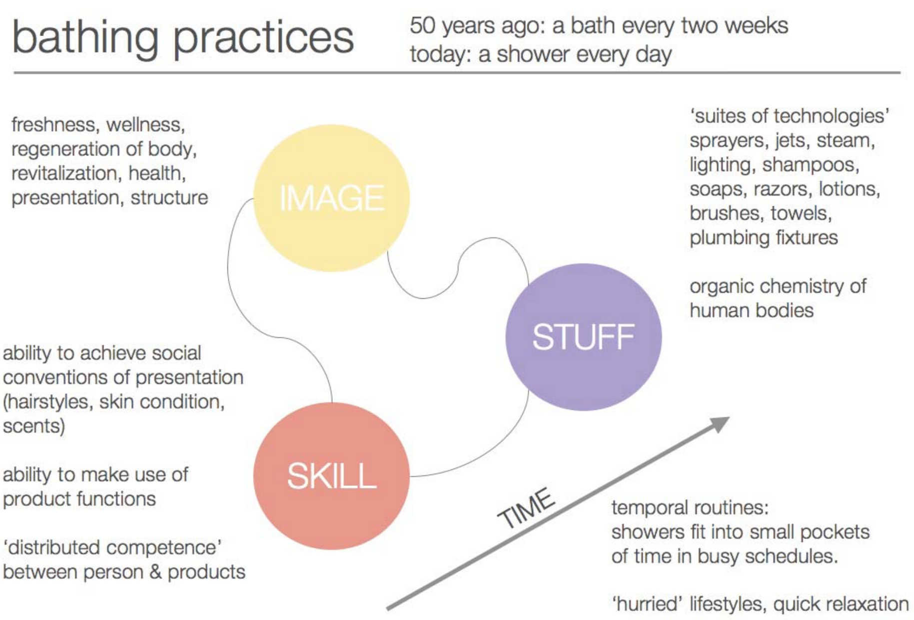

Figure 4: Bathing practices (Bakker et al. 2008, based on Shove 2003)

Figure 4 shows the relation of elements of bathing practices. Comparing practices of 50 years ago and today shows that skills and stuff have only marginally changed (except for new shower heads or the large scale diffusion of (multiple) showers/bathtubs in every household). Mostly, the images have changed and now are coupled with wellness, freshness, a form of presentation of self and relaxation in the accelerated every-day life. This change of images has consequences on patterns of bathing and visible effects on water demand (and, thus, heating energy use for warm water).

	1985	1990	1995	1998	2001	2004	2007
Bath	13,1	8,6	9	6,7	3,7	2,8	2,5
Shower	21,2	28,2	38,3	39,7	42	43,7	49,8
Bathroom sink	6,9	4,5	4,2	5,1	5,2	5,1	5,3
Toilet flush	32,7	34	42	40,2	39,3	35,8	37,1
Clothes washing (by hands)	2,4	2,4	2,1	2,1	1,8	1,5	1,7
Clothes washing (machine)	21,6	22,7	25,5	23,2	22,8	18	15,5
Dish washing (by hand)	10,5	9,4	4,9	3,8	3,6	3,9	3,8
Dish washing (machine)	1,1	0,8	0,9	1,9	2,4	3	3
Other (food, drink, other kitchen faucet)	7	12	10,2	9,4	9,8	9,8	8,8
Total	116,5	122,6	137,1	132,1	130,6	123,6	127,5

Table 1: Water demand in litres per person and day in the Netherlands

(Sources: UNEP (2003); Foekema et al.(2007), Henk et al. (2008) , Lisanne van Thiel and Boris Lettinga watergebruik thuis 2007, Report for VEWIN Vereniging van Waterbedrijven in Nederland January 2008; N. Matsuhashi (2009)

The table above shows that although half of the households in the Netherlands now own a water-saving showerhead, water consumption due to showering has increased by 30% in the past decade, as people tend to shower longer and more frequently. This reflects how the change of images (rules of signification) led to a change of practices from bathing every two weeks to taking a shower on a daily basis for relaxation. At the same time engaging in the daily practice of showering reproduces these meanings and the elements of the corresponding socio-technical regimes (systems of provision, markets, energy provision etc.).

One approach to change bathing practices is the design of transformational products (Hassenzahl and Laschke 2013), which aim to disturb routines and actively involve users in a dialogue with the product. To save water, the “Shower Calendar” was developed (Laschke et al. 2011) as a transformational object (see figure 5), which gives feedback to users on their water demand and involves them into a contest i.e. with other family members, thereby fostering awareness and communication.

Figure 5: The Shower Calender (Source: http://hassenzahl.wordpress.com/?s=duschkalender)

The coloured dots are displayed electronically and represent the individual amount of water use, starting at 60 litres and decrease in size when water is used. Water saving is not automated but people are actively involved and reminded to take action, thus, fostering learning processes. This prototype was evaluated in two families for one month; results showed a significant reduction of water use for the parents while the children's water demand showed less significant results. Laschke et al. conclude that the complex situation in families and individual differences should be considered. The participants reported a positive feeling towards the calendar, which would relate to design of the transformational object: positive feelings result from the non-judgemental, non-coercive feedback, the direct type of feedback enables immediate water reduction and the individualised information supports communication and initiates a "competition" for water saving.

3.2 SCP through new social practices and their diffusion

Following the discussion in section 3.1, transition is most importantly a transition in social practices. Under this perspective the concept of social innovation, as Howaldt and Schwarz (2010) frame it, appears very fruitful. They define social innovation as the intentional attempt of actors to reconfigure social practices in a designated field of action, aiming to solve problems better than it is possible on the basis of established practices (Howaldt and Schwarz 2010, 89). Similar to technological inventions, social novelties can only be called innovations when they are broadly accepted and thus become momentous. Drawing on Rogers (2003), Howaldt and Schwarz describe different phases of innovation: agenda setting, matching, redefining, clarifying and routinizing. For successful diffusion of social innovations they would carefully need to be adapted to the social context in order to be accepted.

How can new sustainable social practices be developed?

The literature of sustainability science on design and support of transition processes shows that transdisciplinary methods are necessary (i.e. Scholz et al., 2006; Schneidewind, 2010; Lang et al., 2012). Social innovations should also be developed in action research oriented methods (Lewin 1951; Talwar et al. 2011), involving relevant stakeholders and users in the socio-technical system at hand. Regarding the social acceptance and context dependence of social innovations, sustainable social practice cannot be "dictated" from outside a system. Much more the actors in the system must be involved and solutions should be developed and evaluated in co-creation processes – accompanied by sustainability science. Doing so, a higher chance of successful diffusion, acceptance and satisfying user experience can be expected. The main limitations of practice theories have been discussed above: focus on routines, possibility to explain change *but* not under which circumstances actors might more likely leave the routine reproduction of practices and no competencies of actors are considered. Transdisciplinary methods are one step towards better acceptance of reconfigured social practices and possible new technologies involved. Further supporting methods are discussed in the following.

How can sustainable social practices diffuse?

To answer this question, it needs to be analysed when a large number of actors in the field are ready to leave regime practices. The following figure represents our extended SCP Transformation model and illustrates the idea of reconfiguring regime practices for transition.

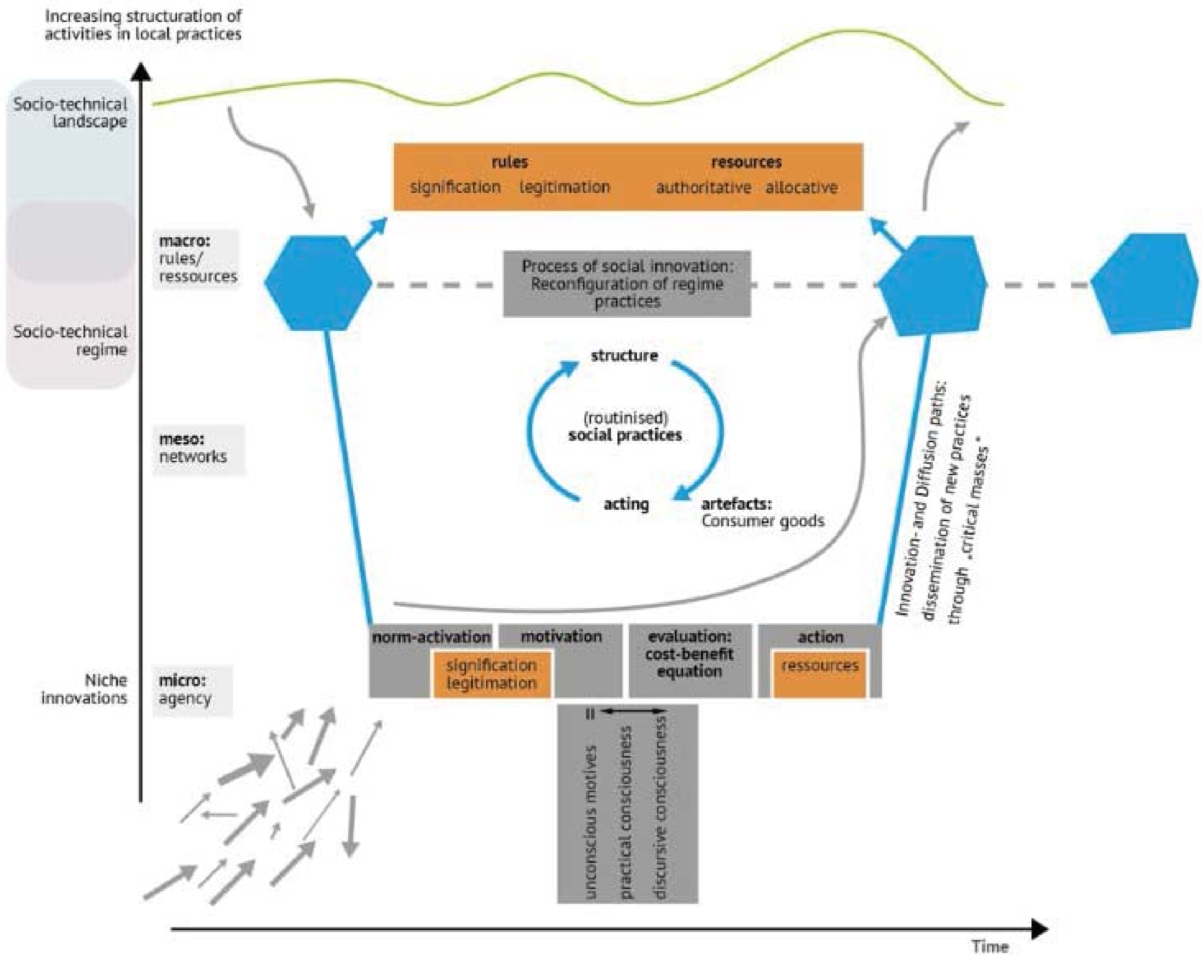

Figure 7: The SCP Transformation Model of social practices (own depiction based on: structuration theory by Giddens (1984); norm-activation model by Matthies (2005), related competencies according to Stengel et al. (2008); „bathtub-model" of social change by Coleman (1991), and adaptation in Liedtke et al. (2010); Theories of social practices, i.e. Reckwitz (2002); Warde (2005); Shove (2010); Watson (2012), compare 1)

The SCP Transformation model is intended to show the following relation between established regime practices and new offerings of alternative practices (i.e. in niches). Actors usually routinely draw on the virtual sets of rules and resources, present in memory traces, to enact social practices, which are institutionalised and fitting for the regime, as long as regime practices are not challenged (either by social innovation in niches, which i.e. show different images in practices, nor by personal ecological norms). Because of their deep institutionalisation, many of such routine practices draw on rules present to actors only on what Giddens calls the practical consciousness. As Matthies (2005) shows, habits are an important aspect of deciding for or against environmentally protective behaviour. Actors who decide to leave a routine practice or to stick to it, first need to activate their personal ecological norm through awareness. Social practice theory hereby enables a sociologically informed view on habits, as practices represent a routine kind of behaviour but also provides the link to institutionalised and shared beliefs, norms and resources. If ecological norms are activated, actors will start to reflect on the underlying rules and resources. Still routine practices are not likely to change as long as social costs of routines are low or even beneficial – practices and the corresponding regime is still reproduced by the majority of practioners. In this case routine practices drawing on rules from practical consciousness without explicit reflection have low costs for actors. In the motivation phase, the different personal and social motives become relevant. These two phases, thereby, mainly draw on rules of signification and legitimation associated to the practice. Social costs arise through expectations of relevant others in the personal (friendship) network – friends who stick to a routine practice might expect the same kind of behaviour or question ecological motives from the perspective of interpretations considered "normal". After the decision, the re-definition loop occurs - thereby, learning of the new arrangement of rules and resources can take place and existing norms can be redefined; either positive or negative in terms of environmentally equitable behaviour. Moral and social costs will rise when images and meanings in a social practice, associated with a product used in a practice, change to negative (Welfens et al. 2008; Stengel 2011; Liedtke et al. 2013b; Hassenzahl 2011). Images (interpretative rules in Giddens' terms) change when new interpretations become more dominant. The diffusion of a new practice ultimately leads to a re-institutionalisation of new sets of rules and resources, that is to say new elements of practices.

The role of networks for diffusion of new practices: Shaping networks to spread new meanings

Networks[3] are considered one of the most important factors influencing the diffusion of innovations (Rogers 2003), also of social innovations (Howaldt and Schwarz 2010). Change agents (Kristof 2010) can support the diffusion of new practices through their specific relational competencies in innovative regional networks (Baedeker 2012) and who require a specific skill-set (Bliesner et al. 2013). The networking skills of change agents are critical for successful diffusion of social innovations as well (Moore and Westley 2011). In personal networks of actors in socio-technical systems, social network analysis has shown how sayings and opinions spread (social influence) and shape network relations (selection). Accordingly, networks are one of the most central concepts to understand the diffusion and acceptance for new practices. Once a critical "mass" of actors is informed about sustainable consumption practices, norms are activated, sayings offer a contradictive interpretation to dominant rules of signification (i.e. through image campaigns) and important persons in one's own network expect ecologically aware behaviour, we hypothesise that a self-reinforcing process (Hassenzahl and Laschke 2013; Liedtke et al. 2013??) will destabilise the existing socio-technical regime and support transition – finally establishing new social practices as "normal".

The SCP Transformation Model aims to show how not sustainable social practices, established at a point in time t_1, can be transformed towards higher sustainability through new social practices (social innovation) and their institutionalisation at t_2. With this institutionalisation parts of a newly configured socio-technical regime are established and transition cycles begin again.

[3] By networks we refer to the sociological concept as any kind of relations between actors, not only organizational networks between collective actors or the kind web 2.0 media now often named social networks (i.e. Prell 2012).

Drawing from this discussion, a combination of the following approaches to support the development and diffusion of newly configured practices appear beneficial. These following approaches have been applied and partly developed in different research projects conducted at the Wuppertal Institute:

- information campaigns to raise awareness and support norm-activation (Liedtke et al. 2010)
- approaches drawing on ecologically true prices (Weizsäcker 1994; Schmidt-Bleek 1994; Schmidt-Bleek and Wiegandt 2009; Meyer 2009) could apply in the *evaluation* phase, which argue actors would choose against ecologically problematic consumption as soon as prices rise.
- Stengel et al. (2008) show how the phases of norm-activation relate to specific competencies. Such competencies can be derived from the concept of Education for Sustainable Development. At this point the model is open for educational aspects, specifically the method “open didactic exploration (ODE)” can be applied addressing interpretative patterns (Bliesner et al., in prep.; Bliesner et al. 2013).
- Change of interpretative patterns: Meanings and images in social practices (see examples below; cf. Reinermann and Lubjuhn 2011; Liedtke et al. 2010)
- Personal social networks (Baedeker 2012, Kristof 2010)
- Change agents (Kristof 2010; Bliesner et al. 2013)
- Change agents in institutional networks (Baedeker 2012)
- Sustainability in global value chains (Geibler 2010)
- “Open exploration scenarios (OES)” and (development of) competence profiles of change agents (Bliesner et al. 2013, Liedtke et al. 2013) of which the SCP Transformation Model forms the theoretical basis

Most of these approaches cannot be discussed in depth in this paper. The aspect of meanings as one central approach will be exemplified in the following.

4. Empirical examples for diffusion of new social practices: Meanings, networks and norm-activation

In this section we review empirical case examples of change in images and meanings associated with products as they were worked out by Stengel (2011; 2013): cars, cigarettes and energy use in Japan after the nuclear accident in Fukushima. The change processes were always accompanied by communication strategies of different groups and resulted in a change of social practices.

Communication strategies have been developed in different project contexts at the Wuppertal Institute, i.e. for resource efficiency (Liedtke et al. 2010) or „using instead of owning products“ (Leismann et al. 2012) and education entertainment (Reinermann and Lubjuhn 2011). . Such strategies should always be designed product- and target group specifically; i.e. it can be expected that meanings associated with mobile phones or cars vary product-specifically while in cosmetics meanings vary rather milieu-specifically.

As Stengel (2011) shows, a change of patterns of meaning occurs through three steps:

- **Consonance**: majority of actors in an „interpretative elite" agree on a new definition; contrasting interpretations do not gain influence.
- **Persistence**: This new interpretation is maintained for several years
- **Focusing**: New meaning is taken up by mass media and distributed for a longer period of time

Cars

The meaning of cars changed fundamentally in the 1920s: When the number of cars on American (but also European) streets increased and the number of accidents increased as well, a strong public pressure led to speed restrictions in most cities throughout the USA. These reduced speed limits made car driving less attractive to many people, from 1923–1924 there was even a drop in car sales in the USA – car drivers were stigmatized as „speed maniacs", while their cars consumed space (especially due to parking) and polluted the air. Against this background, the car lobby launched extensive campaigns for road safety in schools and the local press, strengthening the idea that pedestrians have to withdraw from the streets. With that and the successful tackle of congestions by building up a new infrastructure (roads for cars only) the stage was set in the early 1930s for a new era of (urban) mobility.

By the end of the 20th century, the car used to be a status symbol. Now, in the 21st century, it seems to be losing this meaning in society. In many western societies, a growing number of young adults under 30 years do not own a car or are not even interested in attaining a driver's licence anymore (Sivak and Schoettle 2012a; 2012b; Ifmo 2011; Beckmann et al. 2006). Instead, they use public transport or bicycles. The financial crisis and tight economic situation, high investment and maintenance costs for a car as well as the trend of living in cities seem to be the reason for this new picture. Furthermore, the car has become a symbol for climate change and a bad quality of life in cities (Gehl 2010).

Today, the car is starting to lose its attractiveness at least in western countries (cf. Sociodimensions 2010), whereas in Eastern societies, e.g. in China, still the possession of a car is considered as modern, western, and prestigious (Canzler et al. 2008). Here, a critical perspective on individual motorcar traffic has hardly developed so far. It remains to bee seen whether the western shift will happen in China as well as in other newly industrialised countries.

Smoking

Another example of the relevance of altered sayings for the transformation of collective behaviour is the observed cultural change of the cigarette.

For about 50 years, smoking cigarettes was regarded as a „dirty habit“. In 1904 only five per cent of the American adults were smoking cigarettes. However, after World War I cigarettes became a symbol of maleness, brotherhood, a break with conventions, and a symbol for the equalization of women. This shift was triggered by the distinctive performances of American soldiers and nurses smoking cheap cigarettes during the war. In the following decades the number of smokers increased rapidly and in the 1970s, half of all adults smoked in the USA.

Since 1980, the meaning of smoking is deteriorating steadily. Smokers are being ruled out of public spaces, the cigarette is turning into a lower class-symbol and Hollywood movies show less often protagonists, who smoke (Brandt 2009; Sargent and Heatherton 2009). The number of young adults, who smoke, has been decreasing steadily; in 2011, only 22 per cent of Americans were smokers. Additionally, this trend has probably been supported by strongly rising prices for cigarettes.

Again, the situation is different in China. A critical awareness has not yet been developed for smoking: Only 20 per cent of the adults in China believe smoking causes cancer, or other health problems, and 53 per cent of adult Chinese men smoke (WHO 2010). Nevertheless the authoritarian government is trying to ban smoking of public indoor spaces by law since 2011. However, due to the positive image of cigarettes and smokers the ban is often being ignored (Haas 2011). Changing the doings without changing the sayings first is a difficult endeavour even in authoritarian systems.

Only due to a redefinition of sayings, authorities could enforce the smoking ban even in pubs and clubs, i.e. a change of doings, in many countries successfully. Changing the doings first would have provoked a lack of understanding, occurred for instance during the American prohibition. Hence, the cultural change (sayings) provides the legitimation for a normative change (doings). A large-scale longitudinal network study on smoking cessation by Christakis and Fowler (2008) supports the relevance of important others in social networks for the spread of changing practices. Their study with more than 12,000 people in the USA over the past 30 years shows that groups of smokers tend to quit together and smokers get increasingly socially marginalized .

Energy saving in Japan

The nuclear disaster of Fukushima in 2011, forcing thousands of people to drastic energy saving measures, can be analysed taking into account the sufficiency theory (Luhmann 2012). Following this dramatic event, several nuclear power stations were turned down and Japan had to cut down its energy consumption by around 15% within a short period of time. In order to achieve these energy savings, different sufficiency measures were implemented throughout the country, tackling energy savings in non-elementary services without major technical innovations. This national energy saving programme, limited to several months, was named setsuden, which means „save energy” (The Japan Times 2011).

During this period, certain changes and circumstances were accepted, which would be an unacceptable “discomfort“ in normal times. A large number of people participated in this energy saving measures, therefore, energy saving practices became normal. The normalisation of a practice is “perhaps the most fundamental feedback effect“ (Watson 2012) because that enables even those actors' performance, who do not want “to swim against the river”. Then, after a few years, the previously normalised practice turns to an exceptional thing to do. At that point, a new collective routine is emerged.

In Japan, many small measurements and behaviour changes lead to the result of a nationwide saving outreaching the aspired goal in summer 2011. It was found that human behaviours and habits are fundamentally changeable even in a short period of time. In fact, studies show that people are ready to make significant behaviour changes if they know that others act in the same way. This way they do not have the feeling to act extremely, but normally (SDC 2006). Therefore, it is supportive, if others, who are visible to large groups of people, already perform the desired behaviour. In Japan municipalities assumed the role e.g. by reducing lights in the city. By doing so they activated a descriptive norm, also followed by those citizens who have not developed a personal (injunctive) norm for saving energy (Kredentser et al. 2012; Kallgren et al. 2000). In autumn 2011 the period of setsuden officially ended in Japan, consequently the energy consumption rose again.

Conclusions and outlook

In this paper we have introduced the SCP Transformation Model and presented historical case examples (Stengel 2011; 2013) of changing meaning of products and, following, change of social practices and the institutionalisation of new associated interpretative rules. The same can happen by changing other elements of practices (Shove et al. 2012): stuff or skills; therefore, stuff should be designed accordingly to change social practices (i.e. transformational products), also Education for Sustainable Development can support a change of skills. Both against MLP and social practice theories there have been criticisms – practice theories are seen as a too low level of analysis providing very detailed insights but little understanding of system change (cf. Watson 2012). Strucutration theory presents a complex level of analysis, however empirical work is demanding. Thus, our suggested framework foremost indicates the importance to take social practices as the basis for designing transdisciplinary, action research oriented methods.

Talwar et al. (2011) and Lang et al. (2012) systematically present transdisciplinary methods of action research to integrate actors and users into research in sustainable transition processes. Based on their construction of action research approaches we are able to develop a research infrastructure concept together with other European researchers which focuses on the development of low resources and more sustainably designed product-service-systems (possible higher individual and social quality of life, life cycle-wide lowest possible resources consumption). On this basis, the Sustainable LivingLabs research infrastructure and methodology have been developed both as a setting for transdisciplinary experimental research in product-service-systems and was itself developed through transdisciplinary methods together with important stakeholders in the course of several interlinked research projects over the last years. The Wuppertal Institute has conducted a European Design Study on LivingLabs[4] (Welfens et al. 2010; Liedtke et al. 2012b) and further advanced this kind of research infrastructure in the SusLabNWE[5] project and the German SusLabNRW sub-project to develop a product-service-system in the field of heating and space heating (Liedtke et al. 2012a).

In the Design Study a pilot was set up, which used insights from practice theory, combined with co-design and co-creation approaches. Many products are designed for more resource efficiency but without reference to user practices, often resulting in unintended use patterns, which produce much less energy and water savings than expected (rebound effects through wrong application or unexpected user practices, Liedtke et al. 2012). Similarly, user practices appear to have a larger impact on heating energy consumption despite of efficient heating systems or insulation, as a European LivingLab project shows, where a pilot in the field of heating and space heating is currently developed (Liedtke et al. 2012). The key bottleneck to adequately meeting people's needs in future sustainable homes is hence not technology itself, but the way people interact with these technologies and how the living environment shapes user practices. For Living Lab, the pilot broke new ground in at least four respects: instead of pure user research, it asked participants to do experiments in practice; it focused on creativity in 'doing' rather than in making; it used communication technologies enabling the participants to interact and influence each other during the research; and it involved users in both analysis and creative functions, while researchers and designers were involved in looking at their own practices as well. Taking a practice perspective on bathing taught participants and researchers to see showering, the dominant practice, in a different light opening up directions that have a far higher potential for reducing water and energy consumption than technology or behaviour oriented approaches may have. The development process resulted in a prototype to change bathing practices: the 'bucket wash'.

Referring to the target defined in the introduction of designing a sustainable production and consumption system, which contributes to a factor 10 absolute reduction of resource use of our whole society, such innovation research infrastructures can integrate the relevant actors to support a shift of actions and social practices in life- and working styles. Because of its orientation towards systems

[4] The design study was conducted within the 7th Framework Programme of the European Union (2008-2010) in a cooperative project by four academic (led by TU Delft in cooperation with ETH Zurich, Universidad Politecnica de Madrid, Wuppertal Institute) and three industrial partners (ACCIONA, BASF, Procter & Gamble);
The SusLabNWE project, funded by the European Regional Development Fund (ERDF), Pro-gramme INTERREG IVB NWE, aims to set up a European infrastructure of LivingLab test facilities at different locations, which co-operate in user-centred development of sustainability innovations around the home.The focus area of the German consortium (Wuppertal Institute, Hochschule Ruhr West and InnovationCity Management GmbH) is located in the Ruhr area in North Rhine-Westphalia

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thinking and environmental space this approach needs to be continuously evaluated and advanced on the basis of action research methods. Therefore, action and transition research have to be advanced themselves analytically (ex-post and ex-ante) and methodologically to meet the challenges of sustainable development. This is true for respective competencies of researchers, lecturers and students for transdisciplinary action research to be applied as well (cf. Schneidewind and Singer-Brodowski 2013).

For application in action research methods, this underlying theoretical framework of the SCP Transformation Model needs further additions, which are being developed and can be oriented along the Transition Management Cycle (Loorbach 2010): System analysis (ex-post) and transformation scenarios (ex-ante target knowledge); system transformation methods to generate different solution types; systems- and transformation knowledge (based on multiple data indicators and empirical research methods to enable new forms of evaluation); inter- and transdisciplinary systems competencies to enable systemic solutions.

Thus far, our approach certainly needs further refinement: there is little to no integration of social differentiation and milieus in our model. First methods have been developed, so that we are able to combine macro statistics with data from social milieus, further specified down to different households and individual actors. Both social and resource consumption profiles of individuals as well as their related social groups can be derived (i.e. competence profiles, individual and social needs, interpretative patterns, different behaviour in different areas of needs, time management, income profiles und expenditures, resource use per performance of social practices or area of needs, communication patterns) and socio-technical regime criteria (i.e. local and regional governance structures, political and economic frameworks, drivers and barriers of sustainable production and consumption). These are just some first ideas which show that there is no simple model possible and need to be further elaborated.

Furthermore, network influence should be studied more deeply to understand the diffusion of social innovations (like ESD) and their long-term implementation (Hasselkuß, in process).

Finally the presented model may seem over-complex and too broad. However, change processes in complex systems are naturally complex and low resource and resilience strategies need to take this complexity into account. People permanently face complex situations in everyday-life and with some support are well able to manage them.

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Technological innovation systems and sectoral change: towards a TIS based transition framework

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Abstract

In this paper we develop the building blocks of a framework for studying socio-technical transitions from a technological innovation systems (TIS) perspective. A socio-technical transition is regarded as a long-term process in which new technological innovation systems emerge and mature, while existing ones are destabilized and decline. In the course of such a transition, existing socio-technical systems such as the energy sector or the transportation sector change fundamentally both in terms of overall structure and the set of technologies they use. We suggest distinguishing TIS in terms of maturity (nascent, emerging and mature TIS) and elaborate on the interactions of different kinds of TIS. On this basis we present first ideas of how to conceptualize the maturation and decline of TIS in a broader context, which then serves as the inroad for our understanding of socio-technical transitions at a sectoral level. The building blocks we present are work in progress and we happily invite transition scholars to comment on them.

1 Introduction

In the last decade there has been a strongly increasing scholarly attention for studying transitions of socio-technical systems (Geels, 2010; Smith et al., 2010). Such transitions are major transformations in the way societal needs are fulfilled. They are characterized by long time frames, involvement of many stakeholders, very complex societal dynamics, and radical technological and institutional change.

One reason for this interest in transitions is the widely shared observation that current pathways of economic growth are not sustainable (Rockstrom et al. 2009) and that alternative ways of fulfilling societal needs are necessary in order to reduce irreversible changes in our natural environment. In the literature, transitions towards more sustainable modes of production and consumption have been studied under the label of “sustainability transitions” (Markard et al., 2012).

The emergence of new technologies is a key process in sustainability transitions. New technologies become alternatives for established technologies and possibly substitute them. As a consequence, existing systems of production and consumption might undergo fundamental change through the emergence of new technologies. Such far-reaching changes are particularly likely if new technologies differ strongly in terms of technological characteristics or knowledge base (so called radical innovations). Christensen (1997) made a useful distinction between sustaining innovations that strengthen the market position of existing industries and disruptive innovations that challenge existing business models and often lead to severe changes in industry structure.

The technological innovation systems (TIS) framework has emerged as a powerful framework to study the development of radical and disruptive innovations and the formation of new industries (Bergek, Jacobsson, Carlsson, et al., 2008; Hekkert, Suurs, et al., 2007; Markard and Truffer, 2008). Scholars have analyzed the socio-technical conditions under which radical innovations emerge and derived recommendations of how to strengthen the development and diffusion of novel technologies through facilitating the build up of technological innovation systems.

In the field of energy supply, for example, TIS studies have analyzed the emergence of PV (Dewald and Truffer, 2011; Vasseur and Kemp, 2011), biofuels (Suurs and Hekkert, 2009), fuel cells (Musiolik et al., 2012), wind energy (Bergek and Jacobsson, 2003), or biogas (Markard et al., 2009; Wirth and Markard, 2011). In fact, there has been quite some recent research on the dynamics and particularities of technological innovation systems in the energy sector (Truffer et al., 2012).

A defining characteristic of the TIS framework is a focus on a selected technology. The technological innovation system consists of actors and institutional structures that contribute to the development and diffusion of a specific technology. TIS scholars want to understand why it has developed in a specific way in the past, how it can be supported or what its prospects are. The main hypothesis is that well functioning innovation systems positively contribute to the success chances of innovations.

While this focus has facilitated much of the progress in TIS studies in recent years, it has distracted scholars from taking a broader view on the transformative effect emerging technologies have on existing socio-technical structures in their context. In other words, TIS studies are limited to gaining insight in the emergence of innovations and have neglected to explicitly conceptualize the many other processes that are relevant for socio-technical transitions. These include the co-development of emerging technological fields, which may encompass both competition and complementarities, or the competition between established and emerging technologies.

In this paper, we take the next step and develop a view on sustainability transitions where the dynamics are explained through the interplay of different technological innovation systems. Each technological innovation system, i.e. its specific technologies, actors and institutional structures is embedded in broader context in which other emerging TIS as well as mature TIS (as parts of established sectors) struggle for dominance. These systems, however, do not just compete with one another but they may also have complementary relationships as they maintain common institutional structures, for example. What makes the picture even more complex is that these TIS as well as their various relationships change over time as the systems develop and mature or decline.

The aim of our paper is to develop the building blocks of a framework for studying sectoral change and sustainability transitions from a TIS perspective. We will elaborate on three conceptual parts. First, the differentiation of technological innovation systems in terms of maturity: In an emerging TIS (e.g. carbon capture and storage), the technology is still at an early stage of development (e.g. pilot projects), markets have not yet developed, value chains are still very much in flux and specific institutional structures are weak. In a mature TIS (e.g. wind power), we find well-established products and markets, industrial production and strong institutional structures, which stabilize the system. Second, the context plus different kinds of relationships among TIS, including the resources and institutional fit that they compete for and the structures and mechanisms with which they complement and strengthen one another. Third, the processes and structures with which TIS link up to broader systems (or sectors) that fulfill specific societal functions such as the energy sector. This also includes the transformative processes of TIS growth and the associated institutional changes in their context.

The paper starts with a brief review of the TIS literature (section 2). Based on this we elaborate on the differences between emerging and mature TIS (section 3), the relationships between different TIS and how they change over time (section 4) and how a TIS based transition framework could be derived from that (section 5). Section 6 concludes.

2 Literature review

2.1 Transitions research

So far at least two perspectives have emerged that aim to create insight in the complex nature of socio-technical transitions (Markard and Truffer, 2008; Markard et al., 2012). The first is the multi-level perspective that analyses dynamics of technological transitions by the interaction of three levels (Geels, 2002; Geels, 2011). The niche level is the level where novelty is created and represents the introduction of technological variety. The socio-technical regime level represents stability of existing socio-technical configurations and the landscape level that represents deep structural trend. It is claimed that the alignment of these three nested levels make technological transitions occur. The virtue of the multi-level perspective is that complex societal dynamics are represented in a simple, theory-based model that is easy to communicate and allows for fruitful insights in the aggregate mechanisms that make up technological transitions. The drawback of this approach is that there is less attention for the interaction of many different technologies in socio-technical transitions.

Another model is the technological innovation system (Hekkert et al. 2007; a Bergek et al. 2008). This approach focuses on analyzing the emergence of novel technologies. The virtue of this approach is that it provides a detailed understanding of the processes and mechanisms that characterize the emergence of novelty. It also provides an analytical framework for developing intervention strategies and policies. The limitation of the technological innovation systems (TIS) perspective is that it typically focuses on one new technology and fails to make a clear conceptualization of the overall transition process. The interaction between an emerging TIS and the wider environment is not explicitly conceptualized. Levels like socio technical regimes and landscapes are missing. Thus a true conceptualization of technological transitions is lacking.

2.2 TIS literature on emerging vs. mature TIS

A technological innovation system has been defined as a "set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology and/or a new product." (Markard and Truffer 2008). This definition highlights two points. As with all innovation system concepts there is a strong analytical interest in the creation of novelty, i.e. scholars are interested in how the system performs in terms of knowledge creation, experimentation, market formation etc. However, not just the innovation in the focus is new and subject to changes but also the very structures, which create the novel technology are very much in flux. This is a major difference to national, regional or sectoral innovation system concepts that implicitly assume that the system structures are given and rather stable.

The aforementioned TIS definition also contrasts with the earlier definition of technological systems by Carlsson and Stankiewicz (1991) or the understanding of technological innovation systems presented by Bergek et al. (2008). These primarily emphasize that there is a focus on a specific technology (e.g. in contrast to a region or sector) but do not make a conceptual difference in terms of whether system structures are already established or have just started to emerge. In fact, the technological systems framework has been applied to both established industries such as robots and electronics (e.g. Carlsson and Jacobsson, 1994; Carlsson, 1997) and emerging technologies such as photovoltaics or wind energy (e.g. Jacobsson et al., 2004; Bergek and Jacobsson, 2003).

Whether we use the TIS concept in the narrow understanding (assuming emerging system structures) or in a broader way (including changing as well as stable structures) is also related to whether a TIS is regarded as an analytical construct, whose boundaries largely depend on the research question(s) posed (cf. Bergek, Jacobsson, Carlsson, et al., 2008) or whether it is an entity that can be identified empirically (Markard and Truffer, 2008). While this issue has only received scant attention in the innovation studies literature, scholars seem to agree that technological innovation systems develop and change over time, which implicitly indicates that they are regarded as 'real world' entities.

For example, Bergek et al. (2008) suggest distinguishing a *formative phase* characterized by "… constituent elements of the new TIS begin to be put into place, involving entry of some firms and other organizations, the beginning of an institutional alignment and formation of networks." (p. 419), and a *growth phase*, in which "… the focus shifts to system expansion and large-scale technology diffusion through the formation of bridging markets and subsequently mass markets" (p. 420). In a similar vein, Suurs (xxx) distinguishes between nascent TIS and more mature TIS and identifies differences in key processes that are at play in these phases of development.

For our purpose, it is useful to adopt the perspective that technological innovation systems are real world structural entities, which evolve and change over time and eventually become mature and stable. What is needed, however, are concept definitions and a more precise language to accommodate for this view. We will come back to this in section 3.

2.3 Challenges of emerging technological innovation systems

Actors in emerging innovation systems face many challenges. They need to get the technology right and they need to get the new technology in alignment with the relevant institutions. The latter requires institutional entrepreneurship by influential entrepreneurs (Weik 2011) or collective action (Hargrave and van de Ven, 2006). The existing literature on technological innovation systems strongly focuses on the processes that need to take place for an innovation system to grow and gain enough momentum with the result that the actors in the innovation system manage to maneuver their technology into the production and consumption system. Bergek, Jacobsson, & Sandén, (2008) distinguish between a formative phase and a growth phase. In the formative phase the necessary structures of the innovation system are formed that are necessary for large-scale diffusion that characterizes the growth phase. Thus in the formative phase actors move in, networks are built, legitimacy is gained, resources are mobilized, the technology is developed and first markets are formed. This formative phase is the most critical phase in the emergence of a TIS. High uncertainties around the new technology, large needs for financial resources in combination with small or absent markets, low institutional fit and a lack of institutional power makes this phase highly uncertain and lengthy. It does not just take time to develop new technology, it also takes time to build the supportive structures necessary for the diffusion or growth phase. The time, costs and risk incurred by firms in developing an innovation are inversely related to the developmental progress of building an innovation system for the new technology. More novel innovations require greater change in all parts of the innovation system and therefore greater development time and greater chance of failure.

2.4 TIS literature on TIS context and interactions

It is widely accepted in the literature that technological innovation systems have boundaries, which need to be determined carefully – either on the basis of empirical analyses or in relation to the research question (e.g. Bergek, Jacobsson, Carlsson, et al., 2008; Markard and Truffer, 2008). It is also clear from many contributions that developments in the broader context have an influence of what happens in a specific technological field. Electricity market liberalization, for example, has been reported in many studies on emerging energy technologies as a contextual development with a decisive impact in both positive and negative regards (e.g. Hekkert, Harmsen, et al., 2007; Markard and Truffer, 2006).

However, not many scholars have so far conceptualized the context of a TIS in a more systematic way. One of the exceptions is Markard & Truffer (2008) who suggest that a technological innovation system interacts with both established socio-technical regimes as well as other TIS. In this contribution, regimes, other TIS and landscape factors are depicted as elements (or structures) of the context of the focal TIS. The authors regard the relationships with existing regimes primarily as rival, if the emerging technology represents a potential substitute for the existing technological regime. Interactions with other emerging TIS can be both competitive and complementary (ibid).

Markard et al. (2009) build upon the same conceptualization and introduces a so-called "context analysis" as one of three building blocks of an encompassing analysis of technological innovation systems. The context analysis is briefly illustrated for the case of agricultural biogas in Switzerland. A more profound empirical context analysis, has been presented by Wirth and Markard (2011), who show that governmental support for a relatively mature but still not widely applied energy technology (wood combustion) can have a negative impact on the prospects of an emerging 2nd generation technology (wood gasification) as they rely on the same, limited resource (wood).

The context of a focal TIS, however, can not only be conceptualized in technological but also in spatial terms. For example, Binz et al. (2012) distinguish a national TIS subsystem from the international TIS that includes "globally operating actors, such as transnational companies, but also … small and medium-sized enterprises, research institutes, universities, or intermediary actors involved in technology innovation around the world." (Binz et al., 2012, p.158). Such a perspective can be expected to become increasingly relevant as technological innovation systems mature and span different regions in the world. As case at hand is the photovoltaic industry with strong end user markets in Germany and some other Western countries, major solar cell producers located in China, Germany and the US and OEMs located in Germany and Switzerland, among others.

Together with an explicit understanding and differentiation of structures in the context of an innovation system, it is equally vital to analyze and clarify how context and core *interact*. In the literature on technology and innovation studies, there are many contributions on the interaction of technologies. These include studies on *technological interrelatedness* showing that where two different technologies emerge and develop interdependencies, which might stimulate growth and technology diffusion but also lead to path-dependencies and possibly even lock-in (Arthur, 1987; David, 1985). A typical example is the co-development of a specific hardware and a specific software, which are both compatible with each other but not with other types of hardware or software. Technological interrelatedness played a role in the development of the Qwerty-keyboard layout (David, 1985), the VHS video recorder (Cusumano et al., 1992) or blue-ray DVDs. We witness similar interdependencies between nuclear power plants and a centralized electricity grid in the field of energy supply or gasoline vehicles and the gas station infrastructure in transportation.

Technological interrelatedness, however, might also hinder growth and system expansion if technologies do not or cannot develop at the same pace (bottlenecks, reverse salient). This was the case in the early days of electrification, when direct current power grids could not keep up with the rapidly increasing electricity demand (Hughes, 1983). A more recent example is that the erection of offshore wind farms depends on - and is delayed by - the availability of high capacity grid connection (e.g. Markard and Petersen, 2009), or that the success of electric vehicles currently suffers from both, the low availability of public charging stations and the limited performance of battery technologies (Wesseling et al., 2013).

Interaction of different technologies also occurs when they are linked in value chains, i.e. one technology or product is an input for another (e.g. silicon and PV cells, rare earth metals and power generators), when they use the same inputs (e.g. wood can be used for both paper and energy production) or when they fulfill the same, or similar functions outputs (e.g. crystalline and thin-film solar cells). The latter aspect has been referred to as structural overlap including not only a material dimension but also organizational and institutional aspects (Sandén and Hillman, 2011). Organizational overlap may occur, for example, if a firm develops and produces different technologies or if intermediaries such as industry associations support knowledge exchange in different technological fields. In a similar vein, institutional overlap occurs where technologies benefit from the same regulations. The German feed-in tariff, which supports a broad range of emerging energy technologies, is a case in point.

To summarize, while interaction of technologies is a well-known phenomenon scholars are just beginning to explore what this means for the innovation systems analysis. Also systematic studies of TIS contexts are in their infancy, which means that for developing a TIS based framework of socio-technical transitions, we have to make some additional effort in defining the underlying concepts.

3 Emerging vs. mature TIS

In the following, we conceptualize a technological innovation system as a set of real world structures (e.g. in the form of actor networks), which develop and change over time. As such, it is – ideally – moving from an early, nascent phase with very few actors and linkages to a later, mature phase with a large number of actors and networks. Both phases differ in several regards. These include the number and type of actors, the density of network relationships, the type and specificity of institutions, the degree of structuration and stability, the maturity of the technology and the primary processes within the system.

We distinguish three stages: a nascent TIS, an emerging TIS and a mature TIS (see Table).

A nascent or embryonic TIS is characterized by a low degree of structuration and a small number of public and private actors that mainly focus on research and development. The actors are linked through R&D networks. The primary processes are knowledge creation and diffusion. The technology might not visible yet but appears in the form of ideas and concepts. Variety is high. Institutions are primarily informal and cognitive elements such as ideas and expectations play a key role.

An emerging or juvenile TIS already exhibits a certain degree of structuration with a larger number of actors (e.g. some hundreds), which fulfill different tasks in the system. There are early value chains emerging and intermediary actors such as brokers, consultants, associations etc. The technology materializes in the form of prototypes and early products. Markets are emerging and growing. Variation is still high. The basic processes that take place in an emerging TIS are knowledge generation and system building. The latter refers to all kinds of structuration processes including the build up of value chains, formation of markets, development of educational programs, alignment of regulatory structures etc. In this stage of development many new actors enter the TIS but there are also high exit rates due to increasing competition. Different types of networks like R&D networks, lobby networks, supplier-producer relationships co-exist.

A mature TIS is characterized by a high degree of structuration, clearly defined products, high production volumes, well developed supply chains and stable consumer markets. There are a large number of highly diversified actors. Entry and exit rates are low. We might even see some large industrial actors with high levels of technological competences, market and political power, which dominate some parts of the value chain. A mature TIS is also characterized by established and stable institutional structures that are well aligned with the technology and needs of producers and consumers.

Table 1: Distinction of socio-technical systems in terms of maturity

	Nascent TIS	Emerging TIS	Mature TIS
Synonyms & related notions	R&D network(s)	Technological innovation system[1]; emerging technological field	Production system; industry; established technological field
Degree of structuration	Low	Medium	High
Appearance of technology	Various ideas and concepts	Prototypes, variety of first products	Established products; dominant designs
Primary processes	Knowledge generation	Knowledge generation and system building (structuration)	Production and system maintenance
Actors	Small number of actors; primarily universities & private R&D labs	Medium to large number of actors; different kinds of private and public organizations; high entry and exit rates	Large number of actors; different kinds of organizations; small number of firms that dominate the market low entry/exit
Institutions	Very few mostly cognitive technology-specific institutions	A number of technology-specific institutions which are still changing	Stable formal and informal technology-specific institutions
Networks	Primarily R&D networks	Different kinds of inter-organizational networks	[Established industry networks]

A mature TIS is comparable to an established industry – a notion that is much more common in academic and non-academic use. An industry can be defined a set of firms

[1] In the understanding of Markard and Truffer (2008).

producing the same material, good or service under a specific institutional framework and with a specific set of technologies. These firms operate (and typically compete) in the same business field or market. Examples include the coal industry, steel industry, electric power industry, automobile industry, textile industry, photovoltaic industry, pharmaceutical industry, entertainment industry, insurance industry etc. Note that these are examples at a high level of aggregation with complex value chains including various sub-technologies and -markets.

Industries have also been described in the literature as going through different phases of development, or life cycles (e.g. Klepper, 1997). It will be certainly worthwhile to explore the similarities and differences of our concepts and the industry life cycle literature but this has to be left for later.

In the following, we will also use the term sector referring to an even more aggregated socio-technical system. A sector is a large and very general part of the economy comprising different industries. Examples include the agricultural sector, the basic materials sector, the energy sector, transport sector, water supply and sanitation sector, military sector, health care sector, financial sector etc.

4 Context and interactions

4.1 Context

Every socio-technical system is somehow related to elements and structures outside of the system, which we will refer to as “context” in the following. How this context is conceptualized depends on the purpose of the analysis. In early TIS studies, the context was mostly regarded as a black box, which somehow affected the emerging technology through so-called inducement and blocking mechanisms (e.g. Bergek, Jacobsson, Carlsson, et al., 2008). This understanding of the context confines the analysis to one-way relationships between context and TIS, i.e. the context affects the TIS in some way but not vice versa. As a consequence, context dynamics (if they were part of the analysis) have to be understood as unfolding independently of what is going on in the TIS.

Such a conceptualization of the context is appropriate as long as the primary analytical interest is on the dynamics within the TIS and as long as there are no particular co-developments at play between the TIS and the context (as in the case of complementary technologies, for example). However, if we are interested in studying the development and maturation of a TIS, an explicit understanding of the relationships of the TIS and its context and how these relations change over time (e.g. due to a growing TIS increasingly affecting its context) is necessary. Also when we are interested in studying transitions a clear conceptualization of TIS and the context is necessary since transitions require changes in both TIS and context.

Our conceptual starting point is a focal TIS situated in a broader context. The context comprises the same basic elements as the TIS, i.e. actors and institutions, which are interrelated through different kinds of networks (Figure 1).

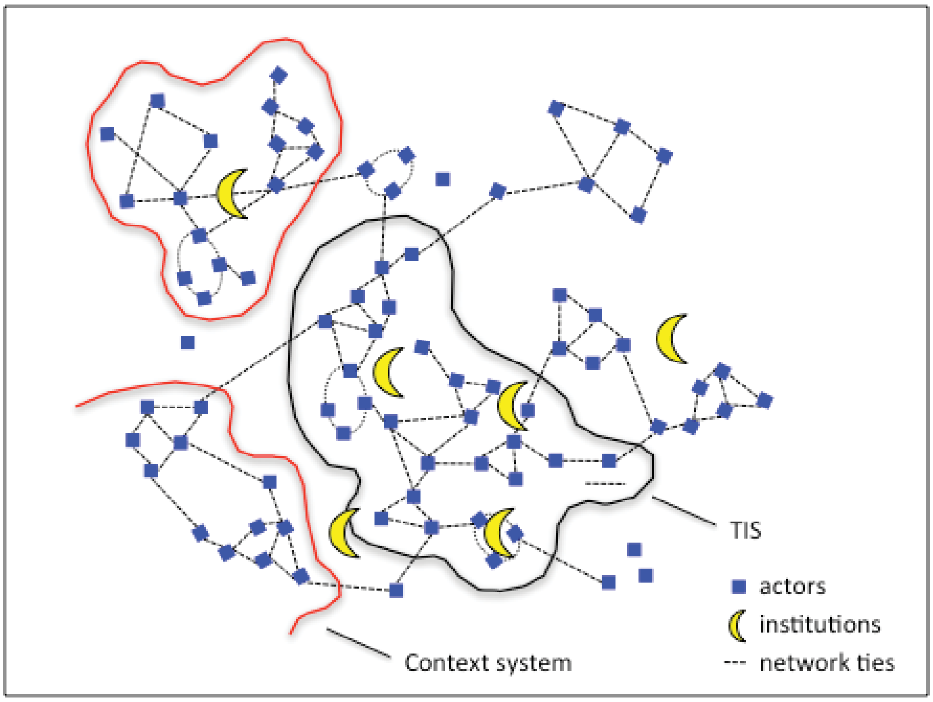

Figure 1: Technological innovation system in a broader context

Going beyond this very general conceptualization, we suggest distinguishing *other socio-technical systems* at a more aggregated level as central structures of the context. These include other TIS in different stages of maturity as well as entire sectors (cf. Wirth and Markard, 2011). Sectors are understood as large socio-technical systems (cf. Hughes, 1987), which fulfill specific services for society at large (Markard, 2011). Examples include the energy sector, transportation sector, agricultural sector, water supply and sanitation sector etc. Sectors rely on a set of different technologies in different stages of maturation and – consequently – on different technological innovation systems[2] to provide 'their' services.

Such a model (Figure 2) enables us to study both the interdependencies of emerging technologies (e.g. photovoltaics and novel battery technologies) and the interactions between emerging and established technologies - with the former becoming a potential threat for the latter (e.g. wind power and nuclear energy). Furthermore, we will be able to analyze sectoral change and socio-technical transitions as a result of the emergence of new TIS and the substitution of existing ones (cf. section 5.1).

2 Note that sectors are orthogonal to TIS, which means that a TIS can stretch over different sectors (cf. Figures 1 and 3 in Markard & Truffer 2008). Our understanding of sectors is equivalent to sectoral systems of innovation and production but we have refrained from using the latter concept because it has been used in the literature to study the innovation performance of a sector (Malerba 2004). This is more specific than the use we have in mind.

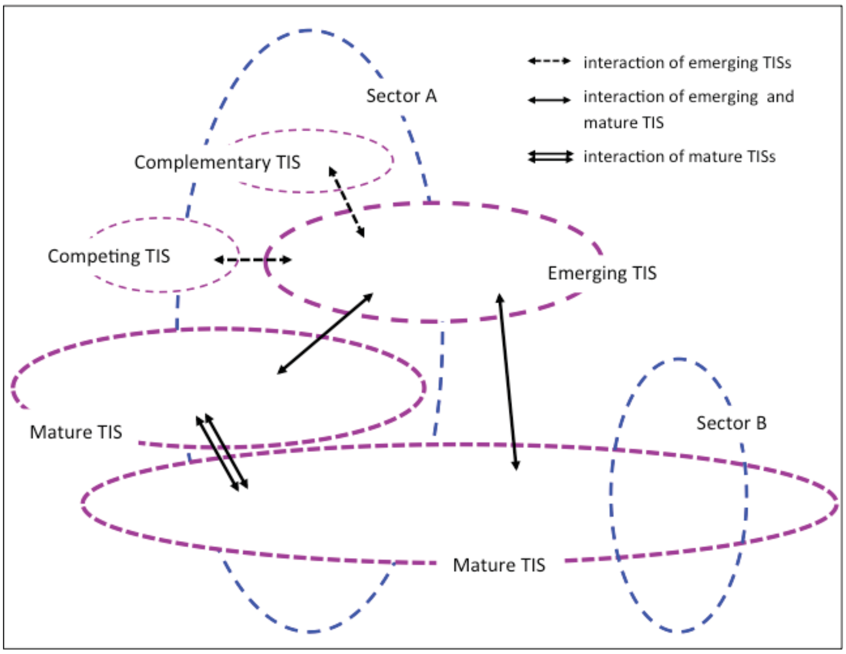

Figure 2: Interaction of different kinds of TIS

How to draw boundaries between the focal TIS and the socio-technical systems in the context depends on the nature of the empirical case and on the research question.[3] In their study on the prospects of a novel biogas technology, for example, Wirth & Markard (2011) assign established bio-energy technologies to contextual innovation systems because they compete for the same resources (here: wood) and the authors were interested in how this competition affects the emerging technology.

We have to keep in mind though that the aforementioned conceptualization of the context is just one among different alternatives. These include a differentiation in regional terms (cf. “geography of transitions”, Binz et al., 2012), for example with a TIS in one country in the focus and the context consisting of the international landscape or TISs in other countries. Other alternatives are the distinction of socio-technical regimes and landscape factors as larger context structures (cf. Markard and Truffer, 2008) or the differentiation of regional and national innovation systems as the background for the development of the focal TIS, for example. The distinction of regimes as central elements of the TIS context is similar to the suggested focus on existing sectors in the sense of highlighting the interplay of emerging vs. established systems.[4]

3 See also Markard & Truffer (2008) on the issue of TIS boundary definition and Bergek et al. (2008) for a methodological proposition of recursive boundary setting.

4 However, using concepts from the multi-level perspective would create an overlap with different theoretical frameworks we want to avoid at this point. The distinction of regional and national innovation systems in the TIS context is nicely compatible from a theoretically perspective but more suitable for studying how an emerging TIS affects established regional and national institutions that support innovation and knowledge creation (and vice versa) than for a TIS based transition framework.

4.2 Relationships

There are different kinds of relationships between technologies that can be transferred to the corresponding technological innovation systems, cf. section 2.4 Two TIS will be *directly* related if the core technology (or product) of a technological innovation system (TIS_1) represents a necessary input for the other (TIS_2). Examples include electric engines to be used in electric vehicles or gear boxes for wind turbines. The resulting dependency will be strong, if TIS_1 represents a key input (or resource) for TIS_2 and if TIS_2 represents a major source of demand for the technology of TIS_1.

A similar relationship occurs, where the core technologies of two or more TIS are required as inputs for the same product. Take for example solar cells and DC/AC converters that are both needed for a solar power plant but are based on very different stocks of knowledge and therefore typically produced by firms in different TIS..

Another type of *indirect* relationships emerges either if two or more TIS commonly use specific resources or if they generate technologies (or products) that fulfill similar functions and are thus substitutable (cf. Sandén and Hillman, 2011). We will refer to Common resource use includes a broad variety of cases. The TISs may rely on the same natural resources (e.g. land, rare earth metals), human resources (e.g. mechanical engineers) or financial resources (e.g. venture capital). They may also rely upon the same infrastructures (e.g. electricity grid, gas stations), institutional structures (e.g. regulatory support schemes) or organizations (e.g. intermediaries, associations).

As a result of these different relationships, technological innovation systems interact in different ways. A basic distinction can be made between *complementarity*, in which progress (or delay) in one TIS causes progress (or delay) in another one and vice versa, and *competition*, in which progress in one TIS causes decline in the other and vice versa (Wirth and Markard, 2011). Furthermore, asymmetric modes of interaction may occur with one TIS benefiting from another and either growing at the expense of the ‘host’ like a parasite or leaving the host unaffected. Finally, a TIS may also negatively influence another TIS without being affected itself.[5]

However, depending on which part of a technology value chain we are looking at, the actual relationships between different TIS are typically more complex. Sub-systems of different TIS can develop in a complementary way while other sub-systems are in competition. Moreover, complementarities and competition can be different compared to the different TIS elements (actors, institutions, resources) we look at. We will address these issues in greater detail below.

Finally, the relationships and the interaction of technological innovation systems might change over time as one or both of them grow, mature or decline. In the next two sections we briefly discuss under which conditions complementarity and competition occur and what their consequences might be.

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[5] See also Sanden and Hillmann (2011) for a description of these different modes of technology interaction.

4.2.1 Complementarity

Technological innovation systems will develop in a complementary way if they have direct relationships in the sense that the corresponding technologies are indispensable elements of a product at a higher level of aggregation. The same holds for direct hierarchical relations, i.e. one technology representing a crucial input for the development of the other (see above).

Moreover, complementarities may also occur in the case of indirect relationships, i.e. if different TIS rely upon common resources and – at the same time – contribute to developing and maintaining these resources. Examples might include common research and testing facilities, common educational programs, knowledge exchange platforms or shared visions of an alternative future of which each of the technologies is an indispensable part.

Complementary relationships of different technologies have been described in the literature under the heading of technological interrelatedness (cf. section 2.4) and we expect these insights to be largely transferable to technological innovation systems. Strong complementarities may have a very profound effect on the overall development in a field due to the inherent contingencies. Especially in situations, in which technologies are in an early stage of development[6] with a priori uncertain prospects, success and failure of specific technological variants may strongly depend on whether complementarities generate mutual benefits thus triggering off a spiral of positive feedbacks or not.

For the analysis of TIS the consequences are twofold. First, TIS dynamics may be highly contingent and strongly dependent on developments in related fields. Second, existing tools for structural and functional analyses should be complemented with paying equal attention to potential developments in the broader context of a TIS. As soon as positive feedbacks from a contextual TIS kick-in the functional pattern of the focal TIS (e.g. resource mobilization, guidance, market formation) might change fundamentally.

4.2.2 Competition

Technological innovation systems compete mostly on the basis of indirect relationships, i.e. when they depend on the same resources (in the sense of inputs) or when they compete for the same customers.

The degree of competition depends on how scarce certain resources are. Resources that are highly abundant or even non-exhaustible such as (non-patented) knowledge cannot be expected to trigger much competition, while scarce or limited resources (e.g. land, venture capital, public R&D funding) may well be the focus of struggles among competing innovation systems.

In a similar vein, the degree of competition also depends on the size and growth of the demand for a specific kind of novel (and substitutable) technologies. In a situation like in

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[6] In situations in which one TIS is already mature and the other emerging, direct relationships are likely to be unidirectional.

Germany, where the electricity sector as a whole is supposed to transform fundamentally, there seems to be ample room for the development and diffusion of a wide variety of renewable energy technologies – even though they are basically substitutable. In a less favorable environment though, wind energy, PV and agricultural biogas may well be competing to be picked by electric utility companies or other operators.

For the analysis of TIS the effects of competing technologies have to be integrated more explicitly into the analysis as they may as well change the functional pattern in an emerging TIS quite rapidly, e.g. as soon as growth becomes suddenly limited, e.g. due to public budget constraints.

4.3 Interaction of technological innovation systems

The interaction of TIS can be studied and conceptualized in different ways. One way is to look at the structural components, another one is to analyze how the interaction on the basis of the key processes, or functions.

With regard to TIS structures, these can be shared among different TIS in the sense that they span the boundaries of different innovation systems. Take for example institutional structures such as carbon reduction goals of countries, carbon taxes, emission trading systems or renewable energy support schemes. These institutions are important for many low carbon technology innovation systems (e.g. PV, wind, CCS), i.e. they stimulate a simultaneous development of different technologies, which can create complementarities (e.g. through knowledge spillovers) but also competition for certain resources. As a consequence, we may expect actors from these different innovation systems to form advocacy coalitions to create and reproduce these common institutions, while pursuing the specific interests of every technology at the same time.

It is not just institutional structures crossing TIS boundaries. Actors can as well be part of more than one technological innovation system. Industrial firms may have stakes in different technologies and associations (e.g. renewable energy associations) may also serve different technological fields. Take for example car manufacturers that develop alternative propulsion systems on the basis of biofuels, electricity or hydrogen, while working on the established technologies as well. In a similar vein, innovation systems may also share technological infrastructures. The biofuels TIS for example makes use of the existing fossil-fuel based distribution and refueling infrastructure and the biogas innovation system uses the gas infrastructure build for the transportation of natural gas.

Finally, structural interaction of TIS also includes the use of resources such as knowledge, human resources, financial resources, natural resources etc.[7] Kamp (200x) for example describes how the nascent wind energy TIS in the Netherlands made use of well trained engineers from the aviation sector. Their training in aerodynamics proved to be very valuable for the development of wind turbines. Nascent and emerging innovation systems

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[7] Note that the term ‘resources’ requires further specification (see for example Musiolik and Markard, 2001). Technological or educational infrastructure or actors can as well be regarded as resources.

are likely to develop much faster when they are able to make use of available human capital 'belonging' to mature innovation systems (parasitism, cf. Sandén and Hillman, 2011).

The interaction of different TIS will also have an effect on TIS functions. Resource mobilization, for example, can be expected to reflect both competition in the case of scarce resources (e.g. arable land used for biogas/biofuel vs. food production or rare earth metals used by many mature as well as emerging energy technologies) as well as complementarities in the case of different TIS creating scale or scope effects in making specific resources available (e.g. venture capital for different kinds of renewable energy businesses, or catalysts for mobile as well as stationary fuel cells).

In a similar vein, legitimacy creation in one TIS may positively (or negatively) affect the legitimation of another TIS. This can be illustrated by the case of nuclear energy technology. For decades, this technology has been highly contested and both proponents and opponents were engaged in framing struggles as to whether it is a high-risk technology that should be discontinued or one of the core solutions to providing carbon free electricity supply (e.g. Garud et al., 2010). Since the strong growth and legitimacy increase of renewable electricity alternatives, these are increasingly presented as viable alternatives to nuclear thus supporting its de-legitimation triggered by the recent accident in Fukushima (Skea et al., 2013). In Sweden, policy decisions to phase out nuclear technology or to continue using it were affected, among others, by whether new renewables such as wind energy were perceived as a legitimate substitute to nuclear (Nohrstedt, 2010).

Guidance of the search may also be affected by developments in 'neighboring' TIS (Bergek, Jacobsson, Carlsson, et al., 2008, p. 415). In the case of fuel cells, studies have shown that the expectation dynamics and especially the hype around the year 2001 (Ruef and Markard, 2010) spanned across such different application contexts as mobile fuel cells for the transportation sector and stationary fuel cells for the energy sector (Budde and Konrad, 2009). Similar effects can be expected across different regions, in the sense of positive developments in a TIS in one country positively affecting the guidance in the same technological field in another country. References to successful (or negative) developments in specific contexts (regional, application-related) can be both relevant for legitimacy creation and guidance of the search.

We expect similar effects to occur for the other TIS functions although there might be differences in terms of how susceptible a specific function is for developments in the TIS context.

4.4 Specific patterns of TIS interaction

In the following, we briefly discuss a (non-exhaustive) number of patterns that might occur when TIS interact. We expect these to be relevant for all the different TIS interacting, i.e. mature vs. mature as well as emerging vs. mature and emerging vs. emerging TIS.

4.4.1 ‘Coalitions’ between TISs

Actors operating in different TIS may form alliances or coalitions to collectively pursue their interests. Such coalitions may be formal in the sense that they have a defined set of members who agree on common goals and governance modes (cf. Musiolik et al., 2012) but more often they will be informal based on existing ties that align along common interests. We will illustrate this with an example from the energy field. When new permissions for building power plants are in the making we may witness competing advocacy coalitions that lobby for competing mature TISs, e.g., actors from the coal innovation systems and actors from the natural gas innovation system. Both lobby for the permission to build power plants and publicly frame technological characteristics in line with prevailing institutions. Coal lobbyists may for example highlight the enormous reservoirs, independence from politically instable regimes and the possibilities for low carbon electricity through co-combustion of biomass and carbon capture and storage. Natural gas lobbyists frame the technology as low carbon, very efficient and flexible, which fits well with high shares of renewables. So, while in competition both strengthen the legitimacy of the core technologies in the energy system. At the same time actors from the coal, gas and nuclear TISs jointly populate energy committees to lobby for the existing energy field as a whole and try to avoid carbon taxes and favorable institutional conditions for renewables.

We expect coalitions to form along common lines of argumentation, e.g. “pro-renewable energies”, “low carbon”, “reliable and low-cost” power generation etc. …

4.4.2 Change and break-up of TIS relationships

With the emergence of novel technologies, relationships among different TIS may change. Some may get stronger while others even break up. In the energy sector, we can think of renewable advocates joining forces with pro-nuclear actors in order to commonly promote the vision of carbon free electricity generation. Alternatively, we may also find coalitions of pro-renewable actors and firms who are committed to gas fired power generation arguing that these are complementary technologies to facilitate the phase-out of nuclear.

As new TIS emerge and become mature the corresponding actors will become more and more influential. If they team up with actors of other, complementary TIS - whether emerging or mature - this might lead to fundamental re-arrangements of power relations and subsequently to some TIS overtaking another set of TIS. We expect the effects of such changes in relationships to be more far-reaching if mature TIS are weakened or even replaced. Such changes in TISs arrangements will then be at the core of socio-technical transitions (see below).

4.4.3 Competition between emerging and mature TISs

The competition between emerging and mature innovation systems is the terms of reference for transition scholars. In multi level model language this is the niche – regime battle. Highly structured mature innovation systems that can be characterized by high production volumes, high institutional alignment, high levels of technological learning, high vested interests, well organized knowledge exchange and advocacy networks and high levels of routinization both at the side of production and consumption are in an uneven battle with emerging innovation systems. The latter can be characterized by opposite characteristics. Technologies are often in an early stage of the learning curve (Neij 1997) and therefore often expensive and not yet technologically optimized.

As a consequence competition between emerging and mature TISs is hardly taking place in the market place. The most salient elements around which the competition centers are resources and institutions. Actors in the emerging innovation systems require resources to innovate. These resources need to be made available to a large extent by actors outside the innovation system like bank, government agencies and science funding agencies. The only thing actors in the emerging innovation system can offer to get access to these resources is expectations about the future potential and performance of the emerging technology (Suurs en Hekkert, 2012). So actors in emerging innovation systems spend significant effort in framing of the technology as solution for urgent problems and raising expectations about future performance. Actors from mature innovations systems may reduce the access to resources by counter framing of the emerging technology or by counter framing the problem that is addressed by the emerging TIS.

Much later in the formative phase, when the technology is much more developed, networks are strong and institutional power is gained, the competition for legitimacy and resources increases.

4.4.4 Competition between emerging TISs

Actors in emerging TISs also compete with actors in other emerging TISs. Often a limited amount of public resources is available for innovation and transition and each actor group has the incentive to gain access to the lion's share of the resources. Also private investors need to decide how to allocate their resources over new technological areas. This stimulates actors to raise expectations regarding their technological field and downplay the promise of competing technological fields.

Studies on emerging technological innovation systems have repeatedly shown that the build up of innovation systems stops or slows down due to shifting societal and political attention for different emerging technologies. The innovation and communication strategies of entrepreneurs in combination with rapid changes in societal and political preferences cause hype and disappointment cycles that accelerate TIS build up and break down existing TIS structures (Negro, Alkemade, and Hekkert 2012, Konrad et al., 2012). A strong competition between emerging innovations before significant markets are formed is generally only beneficial for mature innovation systems since the legitimacy of the competing innovations is questioned.

4.4.5 Competition between mature TISs

Mature TIS are in competition to gain the largest possible share of existing markets. During stable periods with little exogenous shocks, quickly slowly changing rules of the game or quickly slowly developing processes of technological change the relative shares of mature TISs are quite stable. Actors in mature TIS are still focused on innovation to stay ahead of competition within their TIS and collectively also reproduce existing institutions. The reproduction and continuation of institutions cannot be taken for granted, even the most highly institutionalized technologies, structures, practices and rules require the active involvement of individuals and organizations in order to maintain them over time (Lawrence et al. 2001). Zucker (1988) argues that even among institutions, entropy is a natural tendency that needs to be overcome by organized action.

During periods of strong flux in institutions or technological progress, practices to reproduce existing institutions intensify. The current institutional environment is generally advantageous for mature TISs compared to emerging TIS. Changing institutions in favor of emerging TISs are therefore a threat to mature TIS actors and additional efforts are made to prevent change in current institutions. Since different TISs are also affected differently by changing institutions, interesting dynamics in existing production and consumption systems start to occur. While actors in mature TIS are threatened by changing institutions in favor of emerging technologies, they are threatened in different ways and to different extents. Therefore also strategies will differ. In the energy field, increased public and regulatory concerns about climate change has led to diversified strategies regarding the maintenance of legitimacy. Nuclear TIS actors started framing their technology as zero carbon while coal TIS actors stressed the importance of affordability as an important pillar of sustainability. After the Fukushima incident, the institutional cards were reshuffled within 24 hours. Coal TIS actors were now able to provide safe, high capacity and cheap electricity to replace nuclear energy.

5 Towards a TIS based transition framework

5.1 Maturation and decline of TIS

A nascent TIS is influenced by the existing structures in its context. These provide the TIS with resources and legitimacy, for example. As the TIS grows and matures it not only expands and stabilizes its internal structures but also affects and changes structures in its context. This is a consequence of the various forms of interaction discussed before. In other words, there will be a co-development of the focal TIS and the related TISs in its context.

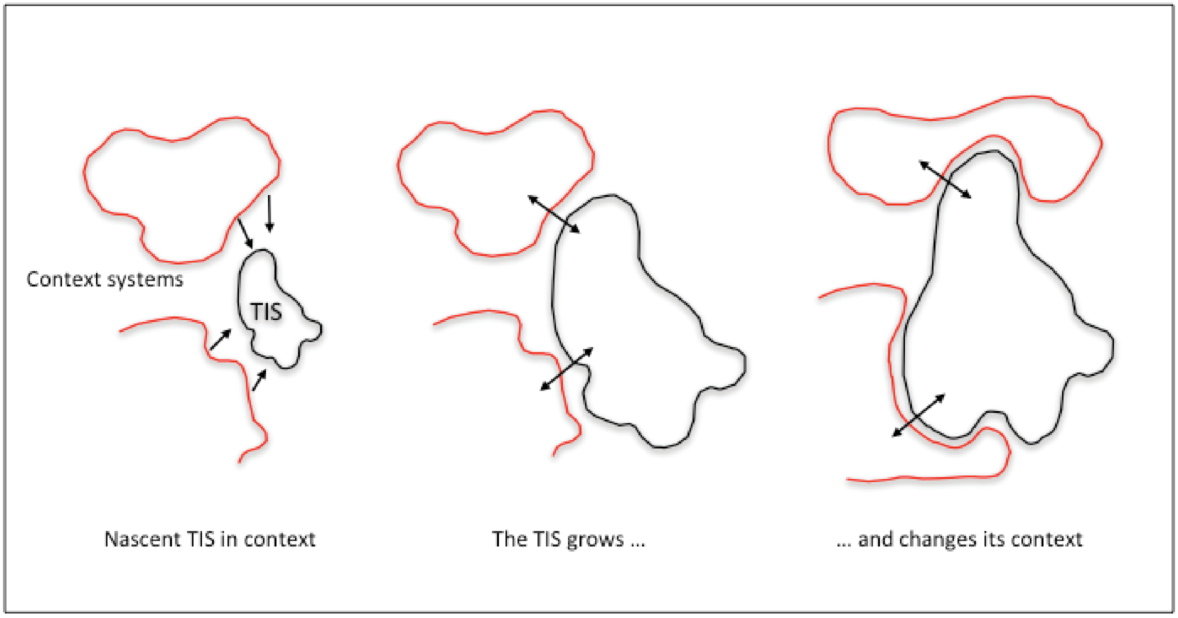

Figure 3: Maturation of a TIS

Another generic process in the life cycle of technological innovation systems is their decline. Driven by changes in the context – be that in mature or emerging TIS – an existing TIS might be destabilized, i.e. its internal institutional structures such as regulatory support or collective beliefs in the future prospects of the technology are weakened and actors exit the technological field. As a result the TIS declines and, possibly, even ceases to exist. The remaining context structures will change and re-arrange accordingly.

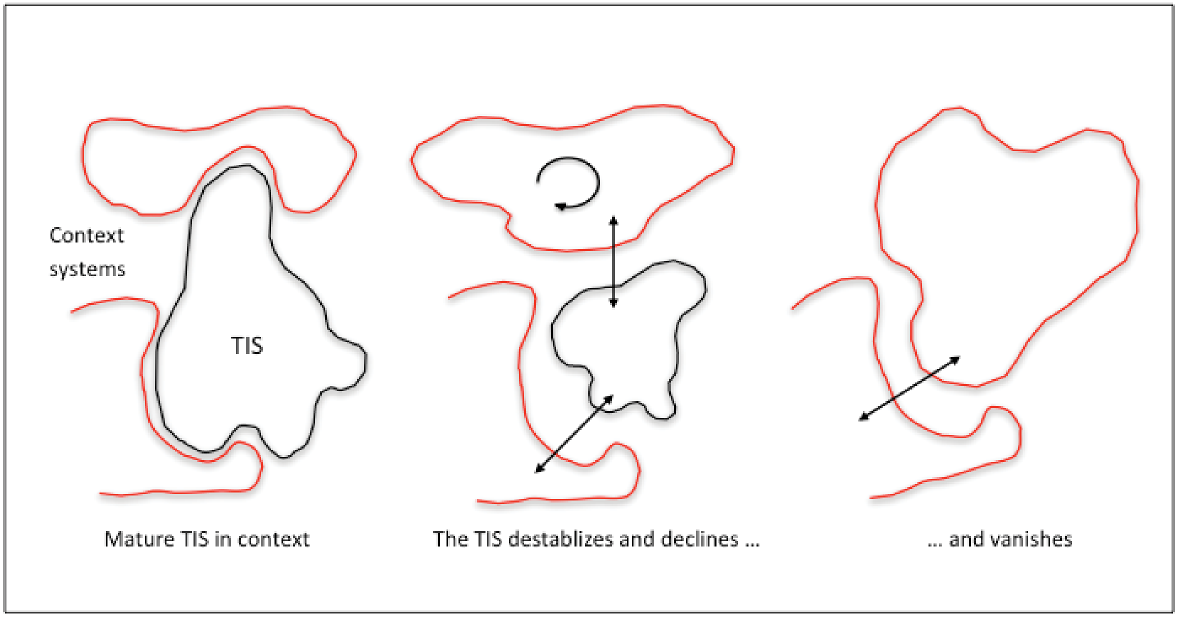

Figure 4: Decline of a TIS

Based on these two generic processes we can now formulate of how a more complex re-arrangement of technological innovation systems can be viewed from a TIS perspective.

5.2 Transition of socio-technical system (sector)

A socio-technical transition has been defined a set of processes that lead to a fundamental shift in large socio-technical systems such as energy supply, transportation or food supply (Geels and Schot, 2010; Markard et al., 2012). Socio-technical transitions typically take decades to unfold. During a transition, socio-technical systems change along various dimensions including technological, organizational, institutional, political and socio-cultural aspects. Transitions typically affect all parts of industry and society including the 'supply side' and the 'demand side' (including life styles and daily routines).

With our framework, we focus on transition processes in which technological change plays a central role. This includes the emergence, diffusion and stabilization of novel technologies as well as the de-stabilization and decline of formerly established technologies. Transitions, which are primarily non-technical (e.g. due to institutional changes as in the case of electricity market liberalization, or due to fundamental changes in the political system of a country), may be addressed at a later point in the development of our framework.

In a socio-technical transition[8], at least one central technology is replaced by another as in the case of water transportation when steam ships replaced sailboats (Geels, 2002). In many cases, however, a broader set of technologies and infrastructures changes in the course of a transition. The reason for that might be technological complementarities (e.g. electric vehicles depending on a re-charging infrastructure) or differences in scale & functionality of the novel and the existing technologies (e.g. different renewable energy sources needed to eventually replace fossil fuels).

In the course of a transition, socio-technical systems will not only change the set of technologies they are ‘using’ but also some or many of their specific systemic characteristics such as structure (e.g. centralized vs. distributed), path-dependency and momentum, interrelatedness, flexibility, resilience etc.

Expressed in the conceptual terms of our framework, a socio-technical transition includes the emergence, growth and stabilization of one or more technological innovation systems and the destabilization and decline of one or more mature technological innovation systems so that the very nature of a sector and the provision of the corresponding products or services changes. Note, that these transitions conceptually include the supply and demand side as mentioned above.

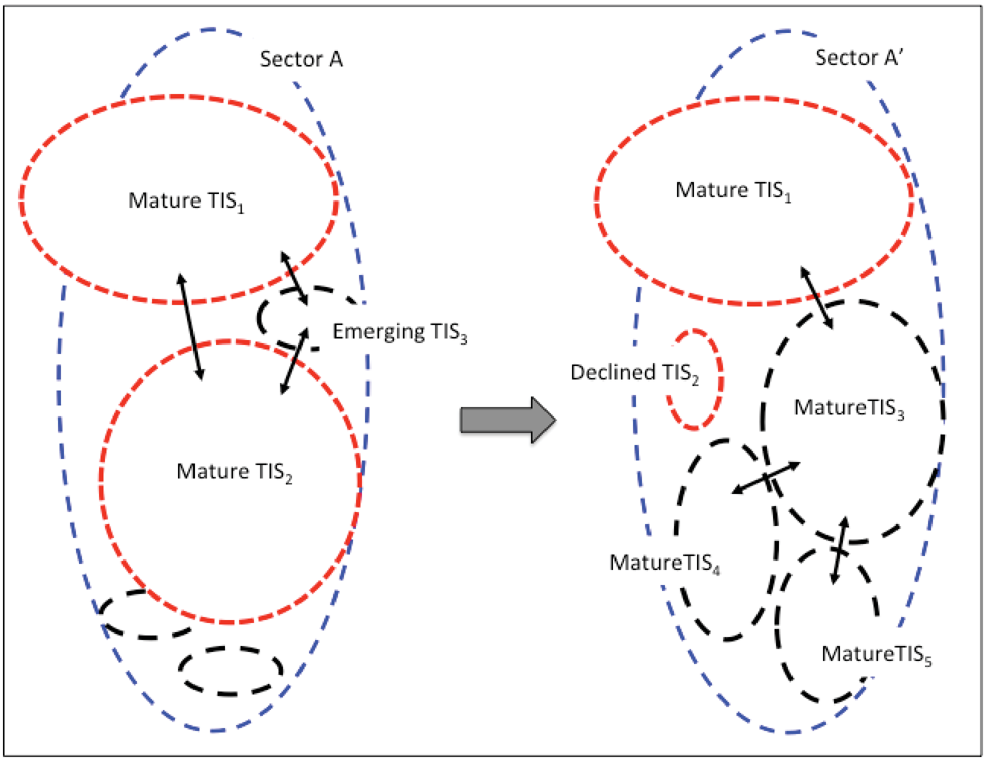

Figure 5: Socio-technical transition of a sector (example)

Figure 5 depicts an example of a transition of a sector, where an established technological innovation systems declines (TIS$_2$) and alternative TIS$_{3\text{-}5}$ emerge and mature, while another core TIS$_1$ remains largely unaffected.

8 We will use the notion transition in the following with reference to socio-technical transitions without always using ‘socio-technical’.

5.3 *Transition as a redirection of resource flows*

The decline of an existing technological innovation system and the emergence of one or more new ones cannot just be expressed in structural terms but also in terms of resource flows. If we look at generic resources such as natural, human or financial resources that are transformed by a TIS as to provide a specific set of products and services, then we can conceptualize a transition as a redirection of resource flows.

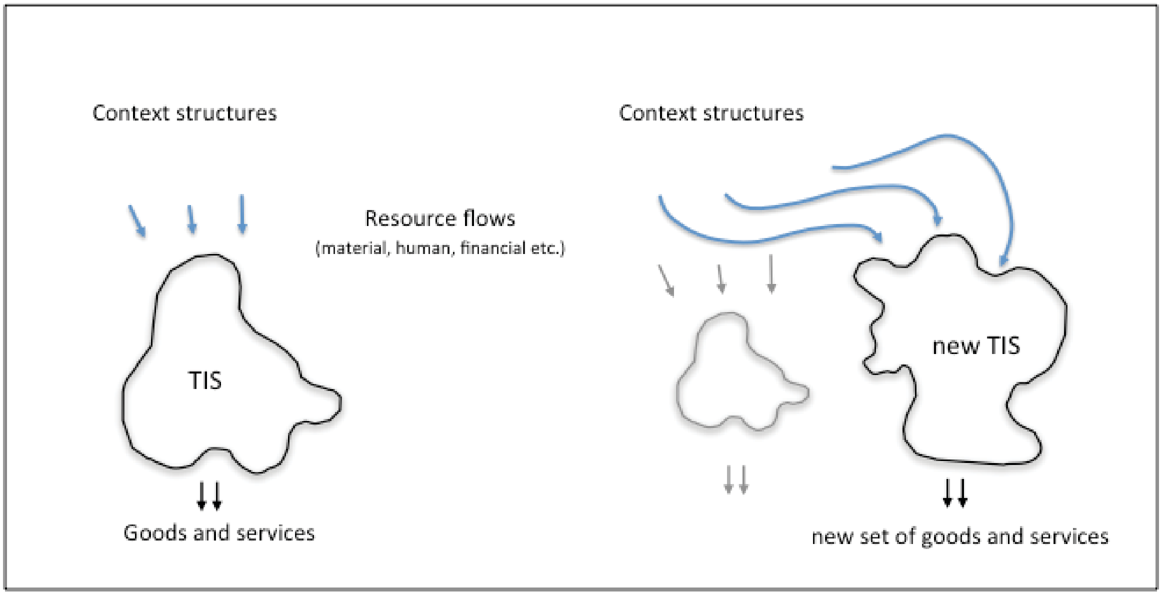

Figure 6: Transition as a redirection of resources

5.4 *Sources of change*

There are different source that generate change and possibly contribute to transitions. These include the creation of new knowledge, institutional changes as a result of power struggles of different actor groups as well as external or developments events triggering change.

Knowledge creation and TIS formation in emerging TIS

Radical and disruptive novelty creation takes place in nascent and emerging innovation systems. Often the key actors in these emerging innovation systems are entrepreneurs and new firms that try to exploit radically new ideas (Farla et al., 2012). However, it is also possible that incumbent firms play a crucial role in the development of radical innovations (Shaz and Krop 2012). The crucial issue is that change is not only driven by the new knowledge created in emerging TIS but also by the structural changes (system building activities) initiated by the TIS actors. Take for example the case of stationary fuel cells, where different kinds of actors joined forces in creating educational programs, lobbied for common support programs and also tried to shape the reputation and public perception of the novel technology (Musiolik and Markard, 2011).

Power struggles towards institutional change

The interactions between innovation systems add to the dynamics of socio technical transitions. Actors within technological innovation systems ally with actors from other innovation systems when this brings mutual advantage. The sector level that encompasses multiple mature innovation systems is generally used as the setting in which shared interests are represented. Actors in emerging innovation systems may also deploy this strategy. In the Netherlands for example actors from different sustainable energy TISs have formed a single lobby organization that represents the shared interests sustainable energy entrepreneurs (Duurzame Energie Koepel). At the same time technology specific lobby organizations may take a strategic position against other sustainable energy options. Generally we observe that actors in emerging innovation systems are less capable in forming alliances, both within the innovation system as between innovation systems (Musiolik et al., 2012; Negro, Alkemade, and Hekkert 2012).

External sources of change

Landscape events such as Fukushima, rising gas/oil prices or the financial crisis affect the inner fabric of sectors as they change the relative position of the different technologies (TISs), which are part of the sectors. They also have an influence on the wider context innovation systems are embedded in. As consequence we might see changing networks, actors and actor positions and resource flows. If the external pressures are substantial we expect to see an increasing degree of institutional incoherence and instability. Thus dominant, well established and conflict free institutional structures are replaced by a more complex institutional environment. Actors in mature, emerging and nascent TIS may link up to these different institutional environments to favor their business and technological field.

5.5 Sources of inertia

As there are several sources of change there are also several sources of inertia. These include the vested interests of incumbent actors, institutional stability and interrelated technologies.

Actors in mature TIS try to maintain their markets

When actors in mature TIS are confronted with novelty many types of responses are possible. Penna & Geels (2012) have introduced the Dialectic Issue Life Cycle Model to sketch the range of reactions by incumbent actors and the order of reactions. Even though the order of reactions stated in Penna and Geels (2012) is not based on sufficient empirical material to allow for generalizations, insight in the set of reactions is very useful. It is important to note that in early phases of development of the new technology, incumbent actors mainly focus on institutional strategies to defend their position. By delegitimizing the problem for which the innovation provides a solutions and delegitimizing the innovation itself they erect barriers for the further development of the emerging innovation system. See also Smink et al (forthcoming) for an overview of strategies deployed by incumbent actors when confronted with potentially disruptive innovations. When the institutional strategy does not provide enough certainty for positive outcomes also innovation strategies are used to outcompete the novel innovation. In the literature this is often referred to as the sailing ship effect (De Liso and Filatrella 2008).

Institutional coherence creating stability

Established institutions are typically interrelated in many ways thus creating very stable structural backgrounds which typically represent barriers for technological change. Take for examples prevailing mobility practices or energy consumption patterns that are again linked to established products and technologies (REF). Same applies to many regulatory frameworks that only undergo incremental changes (REF).

Interrelated technologies and 'systemness'

In a similar vein, also interrelated technologies as well as existing physical infrastructures can come along with a high degree of inertia thus slowing down or preventing socio-technical transitions (e.g. Markard, 2011).

6 Conclusions and outlook

In this paper, we have started to develop the building blocks of a framework for studying and understanding socio-technical transitions, which is based on the ideas and core concepts of the technological innovation systems approach. This is work in progress and many issues have to be elaborated and clarified before the framework can be applied and tested in empirical studies. Still, we are convinced that it will be a worthwhile step forward not only to expand the applicability of the TIS perspective (including its analysis of TIS functions) but also to provide an alternative framework to the existing ones thus creating a broader variety of concepts the community will for sure benefit from.

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Geography of transitions and cluster evolution: the emerging biomass based industry in Southern Sweden

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Introduction

In the past few years, the geography of transitions has emerged as a novel, key area of interest for research on sustainability transitions (Bulkeley et al. 2010, Raven et al. 2012, Truffer and Coenen 2012). Among other things, it has raised attention to the questions whether, why and how do transitions unfold unevenly across the space. Without a proper conceptualization of space, place and scale in transitions, existing theory and research practice has difficulties to answer these questions. Economic geography, and in particular the sub-field concerned with the geography of innovation is a potentially resourceful literature to help clarifying these concepts in a transitions context (Coenen et al. 2012).

At the same time, economic geography is witnessing a so-called evolutionary turn (Boschma and Frenken 2006, Boschma and Martin 2007, Boschma and Martin 2010), becoming apparent in an increasing interest in the spatial emergence of economic phenomena, such as the origin of new industries. Having its roots in evolutionary economics, evolutionary economic geography (EEG) explains the uneven spatial distribution of economic activities and industrial structures based on the micro-level search and selection behaviour of firms understood as organizational routines. Emanating concepts such as related variety and regional branching have added considerably to the economic geography literature as they supplement the weakness of established systemic approaches to innovation by emphasizing the influence of historical preconditions and path-dependencies in regional economic development (Boschma and Frenken 2006, Uyarra 2010).

With the development of the research field, however, some scholars have criticized the strong emphasis ascribed to firm-level routines at the expense of institutions and other actors, for example the state (MacKinnon et al., 2009; Morgan 2012). Due to this bias, evolutionary economic geography has until now only rendered limited explanatory power to factors such as policy interventions and institutions in actively favouring certain development paths (Asheim et al., 2013), in spite of some notable exceptions (Martin and Sunley, 2006). According to pioneering proponents of EEG, the role of (territory-specific) institutions is considered small for explaining where new industry emerges and grows (Boschma and Frenken 2009a). At the same time, others have argued that there is a need in economic geography to better understand institutional evolution over time with regard to regional economic change (Gertler 2010) as there is still a rather limited understanding on the role of public policy for the diversification of regions into new growth paths over time (Asheim et al. 2011). As such, it is not surprising to find that the evolutionary framework as it now stands has a rather poorly developed view of how policy intervention and institutions can work actively in favour of new development paths and, by implication, in steering transitions.

The objective of this paper is to make a contribution to our understanding of industry emergence and development from a co-evolutionary perspective involving technology, industry dynamics and institutions. To do so, the paper studies the evolution of the biogas industry in the region of Scania in southern Sweden. Triggered by policy programmes targeting local initiatives to reduce greenhouse gas emissions as well as experiences and existing infrastructures related to the extraction and distribution of natural gas in the region, biogas activities started to emerge in the late 1990s and early 2000s. During the past decade and simultaneous to technological advances in the biogas area, regional policies have induced further growth of this industry, for example through creating demand for locally produced biogas by setting up environmental goals that stimulate its use in the regional public transport system. The biogas industry constitutes today a visible and emergent industry in the region, involving a network of both public and private actors on the supply as well as demand side of biogas. More precisely, today various utilities, farmers, food and energy companies as well as universities, research centres and support organisations are part of this emerging industry, attracting more actors to enter.

From an EEG perspective, the biogas industry in the region of Scania constitutes an interesting and relevant case to study cluster emergence considering the co-evolution of institutions, firm-level routines and industry dynamics as well as technologies. In particular, it aims at investigating how territorial institutions, in combination with firm-level routines and technology development, can steer regional economic development and evolution along certain development paths. The paper takes a combined institutional-evolutionary perspective by drawing on literature from EEG and socio-technical transitions and seeks to unpack the evolutionary process that led to the emergence of this industry. In particular, the paper aims at addressing the following research questions:

To what extent and how do specific territorial institutions matter for regional industry emergence? How can institutions create and/or lead to path-dependencies in regional economic evolution?

The pronounced analytical focus on the role of public authorities and policies calls for taking a combined evolutionary-institutional perspective on cluster emergence and regional industrial development. The theoretical framework of the paper departs from a discussion on industry emergence in (evolutionary) economic geography introducing concepts such as path-dependence, related variety and regional branching. In order to account for an institutional perspective, the paper draws on insights from science, technology and innovation studies targeting the functions of technological innovation systems regarding transformative technological change.

The paper is organised as follows. The next section presents the theoretical framework of the study, drawing on literature on spatial industry emergence as well as on socio-technical transitions. The subsequent section introduces the empirical case study and analysis, also including an outline of the research design and methods applied in the study. The paper ends with a discussion and conclusion section.

Theoretical framework

Towards a combined evolutionary and institutional perspective on cluster emergence

The objective of this paper is to make a contribution to the understanding of cluster emergence and development from a co-evolutionary perspective involving technology, industry dynamics and institutions. The theoretical framework of the paper departs from a discussion on an evolutionary understanding of spatial industry emergence introducing and discussing concepts such as path-dependence, related variety and regional branching. It also includes a discussion on the role of institutions in this stream of literature. In the further course of the theoretical section and in order to account for an institutional perspective, the paper uses insights from science and technology studies, particularly drawing on the technological innovation systems (TIS) approach concerning how technological change and industrial development can be actively supported.

Spatial industry emergence and evolution

Traditionally, the major part of the literature on economic geography and in particular the subfield of geography of innovation has been focusing on localised learning and agglomeration externalities for innovation processes. The emphasis on the evolutionary nature of innovation processes in EEG responds to an important critique raised against this literature in that they provide snapshots of successful regions detached from their time-space context (MacKinnon et al., 2002). According to Uyarra (2010) the majority of regional innovation system studies can be characterized as "inventory-like descriptions of regional systems, with a tendency to focus on a static landscape of actors and institutions" (p. 129). Having its roots in evolutionary economics, the notion of path dependence is central to EEG, denoting the importance of history and the dependence of past decisions for future events to occur. As a consequence, it is a widely shared understanding in the field of EEG that regional economic development is path dependent. As Martin (2010) frames it, it is "the combination of historical contingency and the emergence of self-reinforcing effects" stemming from critical mass and spillovers that is considered key in steering the "technology, industry or regional economy along one 'path' rather than another" (Martin 2010:3).

Initial attempts in economic geography to understand industry emergence by paying attention to path-dependencies in regional economic development followed the 'window of locational opportunity' (WLO) line of thought (Scott and Storper 1987, Storper and Walker 1989). This literature argues that new industries experience a rather high degree of locational freedom as they put relatively novel demands on their locational conditions in terms of access to knowledge, labour skills and machines. As these requirements are still uncertain and not in place yet when a new industry starts to form, all regions have a similar potential to become host of a new industry (Boschma 1997). Once a critical amount of firms carrying out a new type of industrial activity has established itself in the region, the WLO narrows down because the industry becomes tied to its location. In this manner, an industry becomes locked-in in a specific place (Storper and Walker 1989). With regard to industry emergence, the WLO model assumes that new industries form and shape regional economic spaces (rather than the other way around) and ascribes much explanatory power to the role of chance and accidental events (Nygaard Tanner 2012), thus resonating with the traditional model of technological path dependence as laid out by David (1985) and its emphasis on "historical accidents", "chance events" or "random" action for new technological pathways.

With the evolutionary turn, however, voices have recently been raised for a re-interpretation of path-dependencies, implying a stronger consideration of local (knowledge) resources in shaping regional industrial development paths over time. The literature on EEG gives evidence to path-dependent regional development, stating that firms are expected to diversify into activities that are technologically related to their existing competences. Consequently, regions are assumed to slowly diversify and branch out into technologically related fields, implying that industrial structures are rather persistent in a region (Boschma and Frenken 2009b, Boschma and Martin 2010). This industrial development and evolution is from an EEG perspective explained by knowledge spillovers between firms, assuming that for effective learning to take place a certain degree of cognitive proximity between firms is needed that firms can interpret, absorb and implement new knowledge (Cohen and Levinthal 1990); however, also a certain degree of cognitive distance (or technological relatedness) between actors is needed to stimulate novelty (Noteboom 2000). To address the question of optimal cognitive distance in a context of knowledge spillovers at the regional level the concept of 'related variety' has been introduced (Frenken et al. 2007), stating the positive impact of a variety of different yet technologically related regional industries on regional growth.

Due to its roots in evolutionary economics, the EEG framework has a pronounced perspective on and interest in firms and their routines. More precisely, the pioneering work on EEG (Boschma and Frenken 2006) makes an explicit distinction between evolutionary and institutional approaches to economic geography, arguing that the role of (territory-specific) institutions is small for explaining where a new industry emerges due to the fact that firms develop routines in a path-dependent and idiosyncratic manner (Boschma and Frenken 2009a). This work does not neglect the impact that (territorial) institutions can have on the behaviour of firms, but institutions are treated as conditioning rather than determining the behaviour of firms and regional development as a whole (Boschma and Frenken 2011). Moreover, it is argued that institutions come into existence or become aligned to support a specific industrial activity once it has started to develop (Boschma and Frenken 2009a). As such, EEG follows the general line of arguments laid out in the WLO model in assuming that institutions are responsive to rather than responsible for new development paths.

The mentioned work on EEG has led to a general understanding in the discipline of economic geography that regional economic development is not random but that it relies on historical prerequisites in terms of firms' knowledge bases and routines as well as knowledge spillovers that lead to new industry emergence over time. However, the fact that the pioneering work in EEG puts much emphasis on path-dependencies in regional economic development has been taken up by in the literature, arguing for an incorporation of institutions in approaches to explain path-dependence as well as a stronger consideration of change processes in evolutionary thinking (Martin 2010) or emphasising the importance of processes of collective agency in creating and steering certain development paths (Simmie 2012). Other scholars have mentioned their concern about a 'theoretical relegation' of institutions and social agency (MacKinnon et al. 2009), while others such as Essletzbichler (2009) and Grabher (2009) regard a stronger consideration and inclusion of institutions in EEG as highly relevant for the further development of the research field (Asheim et al. 2013). As such, there is still a limited empirical and theoretical understanding on the role of institutions and public policy concerning the diversification of regions into new growth paths over time (Asheim et al. 2011), as well as a lack of scientific work taking a more holistic perspective regarding the co-evolution of institutions and technology (Strambach 2010).

Institutional context and industry formation

In contrast to the literature on EEG, the literature on socio-technical transitions allows taking a co-evolutionary perspective on technology and industry dynamics and their institutional embedding. A core tenet of this literature is that technology and institutional dimensions should not be analyzed separately when trying to understand innovation. Rather, both aspects are understood in their co-determination over time. The analysis is therefore not restricted to 'technologies' but rather addresses 'socio-technical systems'. The formation of socio-technical systems is conceived as a process of constructing 'configurations that work' (Rip and Kemp 1998) among technological artifacts and their organizational, institutional, infrastructural, use related aspects. During early formation phases largely all major components of a sociotechnical configuration are still in flux: technologies need to improve in performance and cost characteristics, use patterns and user preference have not yet been fully established and institutions to regulate the impacts of the technology are not yet fully spelled out (Callon 1998, Dosi 1982). On the other hand side, established and mature socio-technical configurations, may exhibit strong path dependencies that go beyond lock-in effects based on increasing economies of scale (Arthur 1994), but may be generated by the initial establishment of use patterns (David 1985), standards, infrastructures or institutional structures (Granovetter and MacGuire 1998).

The technological innovation systems approach (TIS), introduced by Carlsson and Stankiewicz (1991) and further developed by amongst others Hekkert et al. (2007), Bergek et al. (2008) and Markard and Truffer (2008), has gained considerable attention in developing a process view on early industry formation. The framework takes a systemic perspective on innovation and considers different actors such as governmental and non-governmental organizations, research institutes and firms as well as different forms of institutions and their interplay as important elements for innovation to take place. Following Markard and Truffer (2008), a TIS can be defined as “a set of networks of actors and institutions that jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a new technology and/or a new product” (Markard and Truffer 2008:611). As a framework for analysis the TIS approach has a rather strong focus on mapping the functionality of the innovation system. In order to assess the performance of the innovation system, Johnson and Jacobsson (2001) and Bergek et al. (2008) have identified seven functions that have to exist around a new, emerging technology (i.e. they have to be carried out by actors and institutions) in order for a technology to diffuse and to lead to new industry emergence: 1) *Knowledge development and diffusion* (generation, diffusion and combination of knowledge in the innovation system), 2) *influence of the direction of search* (incentives for organizations to enter the TIS), 3) *entrepreneurial experimentation* (reducing uncertainty through probing and bringing a technology into practice), 4) *market formation* (development of markets for emerging technologies), 5) *resource mobilization* (mobilization of financial and human capital), 6) *legitimation* (exert influence on the public opinion with regard to a new technology), and 7) *development of positive externalities* (achievement of clustering effects in the emerging industry) (Bergek et al. 2008).

The strong focus on functions in the TIS framework has brought about important insights with regard to key activities in innovation systems as well as understanding processes of technological change and innovation (Hekkert et al. 2007). This allows making statements concerning an active construction and the set-up of a supportive institutional context in emerging clean-tech industries. Furthermore, the TIS framework makes it possible to take a dynamic systems perspective on innovation which allows making statements concerning how specific functions have come in place. The TIS functions target various networks, actors and institutions of the system and makes obvious that for new technologies to penetrate markets, multiple dimensions play important roles. The core strength of the framework on mapping the functionality of innovation systems as well as its underlying strength concerning policy implications to support new technologies is yet accompanied by its weakness in explaining regional differences in technology evolution and development (Bergek et al. 2011, Coenen et al. 2012).

Analysis

Drawing on the previously mentioned insights from evolutionary economic geography and socio-technical transitions, this paper will use the biogas industry in the region of Scania as a demonstrative case of industry emergence, considering the co-evolution of institutions, technologies and industry dynamics (i.e. firm-level routines). The biogas industry is today an emergent industry in the region of Scania, a region that traditionally has been characterized by its agriculture and food industries (producers of organic waste). The region hosts a broad network of public and private actors on the supply as well as demand side of biogas, covering the entire value chain; that is feedstock production, (farmers, municipal water treatment, food industry, households and service sector), pre-treatment, upgrading of biogas and distribution (municipal waste and water treatment companies, energy companies), retail (municipal waste management companies, energy companies, oil companies) and end-use (farmers, public transport companies, food industry, private gas vehicle owners)[1]. Furthermore, universities, research centres and support organisations are part of this emerging industry, having the aim to develop the region into a nationally and internationally leading Centre of Excellence for biogas in 2020. Today, Scania is the county with the highest count of biogas plants in Sweden, producing 0,35 TWh of energy (in 2011) and aiming for an increase to 3TWh until 2020 which equals 10% of the county's energy demand.

The following sections will shed light on the formation process of this industry from a co-evolutionary perspective. The analysis is based on a combination of qualitative research methods. Thereby, personal in-depth interviews with key stakeholders are the main data source, complemented by document studies on publicly available data sources such as websites, strategy documents and annual reports. To date, a total number of 10 interviews with representatives of the industry were conducted, involving primarily representatives from the public sector as well as the industry[2].

Emergence of the biogas industry: unpacking the evolutionary process

Setting the scene: early activities in the region

Activities related to the production of biogas in the region of Scania had their first origin in the beginning of the 1980s and were a reaction to national regulations targeting the reduction of sludge emanating from water treatment at purification plants. Looking back, these early activities can be seen

[1] As clean-tech activities do not underly any industry classification code, it is not possible to identify the industry in quantitative terms and to provide information on its regional economimc impact. In order to make statements on the development of the number of actors, employment and turnover of this industry, manual calculations will be provided in later drafts of the paper, based on a database that is currently under construction (project-related).
[2] The analysis will be complemented by further interviews, also considering representatives from universities.

as one important element for the formation of the industry at later stages; at these times, however, these activities occurred also in other parts of the country and moreover, they were not exclusively targeting the production of energy (i.e. first and foremost the reduction of sludge). However, the biogas produced at the pants at these times was partly used for energy purposes such as for heating the plant facilities. Also going back to the early 1980s, simultaneous activities of a large energy company in the region concerning the supply of southern Sweden with natural gas and the construction of a natural gas grid along the region's west coast can be seen as crucial component for the later formation of the biogas industry. These activities can be seen as a strategy targeting secured energy supply in the southern part of the country as reaction to a national nuclear power referendum in 1980 to decide on the close-down of a nuclear power plant in the region. The experiences with natural gas as a new source of energy in southern Sweden as well as progress in technology development led to the political decision in the mid-1990s to run public city traffic (i.e. the city busses) in the region's capital Malmö on natural gas in order to reduce emissions, improve urban air quality and reduce traffic noise. In other parts of the region, mostly driven by environmental concerns, early attempts were made by some municipalities to collect organic waste from households and to use it as a renewable energy source. Simultaneously in the late 1990s, the previously mentioned energy company became involved in a municipal project targeting pilot experiments concerning the feed-in of biogas into the natural gas grid. Due to this demonstration project, the energy company became an international forerunner in upgrading technologies, targeting the upgrade of biogas to natural gas quality in order to distribute it through the existing grid and making biogas available. At that time (i.e. between 1998 and 2002), the regional capital set up local environmental goals to reduce greenhouse gas emissions and biogas was increasingly considered as a future ambition in public transport.

Industry emergence

The emergence of the biogas industry in Scania gained momentum in 2002, when the Environmental Protection Agency of Sweden (i.e. the national governmental agency responsible for proposing and implementing environmental policies) announced the Climate Investment Programme (KLIMP). This programme targeted local initiatives focusing on the reduction of greenhouse gas emissions and increasing energy efficiency in Sweden. The programme denoted a call for public (local and regional) authorities in Sweden within which also several municipalities in Scania (partly in cooperation with each other) sent in their application. KLIMP constituted a seven-year grant for the period 2002-2008 whereby projects related to biogas where seen as highly important due to the fact that these showed the greatest climate effects. Altogether, biogas projects in 17 out of Sweden's 21 regions received a grant. However, the region of Scania was standing out and received together almost half of the overall grant (of a total of 622 million Swedish krona). As such, the activities and built up of infrastructures in the region of Scania prior to KLIMP during the 1980s and 1990s can be seen as a critical factor for success with regard to the KLIMP applications.

The KLIMP programme can be seen as an institutional setting providing legitimacy for technological change targeting increased energy efficiency and a reduction of greenhouse gas emissions by exerting influence on the general and public opinion of new technologies. The programme can be considered as an instrument to communicate that technological change was desirable by relevant actors. By implication, as legitimacy influences expectations, KLIMP can likewise be seen as means of guiding the direction of search of actors and creating incentives to enter the TIS (Bergek et al. 2008). Hence, KLIMP provided stability and was a crucial element for steering the development along a new development path (or a technological trajectory). However, at that time only comparatively little industrial activities targeting biogas were existent in Scania. Rather, the previously mentioned simultaneous (and largely independent) activities and pre-requisites in the region such as suitable infrastructure and experiences with natural gas, a demonstration project targeting biogas upgrading technologies as well as early activities to collect organic waste from households can be seen as factors constituting an anchor for KLIMP to build on. The development in Scania was further strengthened in December 2002 when the County Administrative Board of Scania published an environmental action plan containing specific milestones concerning the reduction of greenhouse gases in the region. This action plan was worked out by a large number of municipalities, organizations and increasingly also companies in the region.

The network of actors involved in biogas activities in Scania gained increasing foothold in year 2005/2006 when a regional association for biogas stakeholders was founded (Biogas Syd), driven by various public and private biogas actors in the region, involving waste management and energy companies, universities, research centres and municipalities. The association can be seen as bottom-up initiative resulting from a growing need for operational and strategic interaction in the biogas area and it is founded and funded by its members as well as by regional authorities providing basic funding. Thereby, the increasing need for interaction was resulting from the actors' increasing awareness that biogas has a high potential in Scania. First, the region is characterized by a high amount of raw material (biomass) through the region's traditional stronghold in agriculture and food industries. Second, there was an increasing interest among actors such as energy companies and utilities to develop a more environmentally friendly profile. Furthermore and also drawing on earlier experiences with natural gas, research regarding biogas technologies had made substantial progress in the region, leading amongst others to spin-offs from a technological university in the region. The establishment of the stakeholder association, being a support and network organization with the aim to increase the production and use of biogas in the region, can be seen as important towards strengthening the regional networks in the regional biogas field. From an institutional perspective, the foundation of the network organisation can be considered as supporting knowledge development and diffusion, a function considered as central for a TIS and innovation processes in general (Bergek et al. 2008). Network activities are considered crucial for knowledge exchange and interactive learning, and in the region of Scania these clearly profited from different, but related existing industrial activities existing in the region, such as agriculture and food industries. Likewise, the foundation of the network organisation can be seen as means of resource mobilization (both financial and human capital).

From industry emerge to growth

A decisive moment for the biogas industry in the region of Scania was in 2007 when the regional government's public transport committee set up a goal that all public transport in the region should be fossil free in 2020, with sub-goals targeting fossil free city traffic (city busses) in 2015, regional traffic in 2018 and remaining service trips in 2020. In reaction to the announcement of these goals, the company running the public transport in the region – being a publicly owned company and part of the regional authorities – thereupon took the decision to invest in biogas. Important for this decision was the fact that the energy needed for the public transport should be produced locally in order to obtain a direct environmental effect in the region. Biogas was regarded as the fuel with the highest regional potential; attributed also to the more and more developing regional specialization on biogas, as well as to the fact that Scania was considered to possess the greatest potential for biogas production within Sweden. From a raw material perspective, this potential can be ascribed to the previously mentioned stronghold in agriculture and resulting biomass residuals from related industries, the experiences and existing infrastructures for the production of biogas at sewage treatment plants since the 1980s as well as the interest of local waste management companies to collect organic waste from households. Furthermore, it was important for the transportation company, acting on behalf of the regional government, to decide only for one technology and not for several at the same time because of the high investments required; moreover, it was considered important to give a clear and secure signal to the market. The latter can be seen as clear example from the regional authorities to support entrepreneurial experimentation through reducing uncertainty and facilitating concrete actions targeting a specific technology (Hekkert et al. 2008). Moreover, the grant from KLIMP programme, still in place when the regional climate goals were set up, was used for the acquisition of biogas busses and public filling stations. The regional public transport system played thus a crucial role for promoting the development of the biogas industry in Scania as it created a local market for the biogas produced in the region. The decision taken for the regional public transport system led to activities of private companies (such as energy companies) to invest in the (commercial) production of biogas. Since then, various private actors have entered the industry and the number of biogas plants has increased rapidly.

The development of the industry was further supported in spring 2010 when the county administrative board of Scania set up a climate goal for the region, particularly to bring forward the regional production as well as consumption of biogas. The goal implies a total production of 3TW biogas in the region in 2020, which equals 10% of the energy demand of the county. Moreover, Scania shall develop into a nationally and internationally leading Centre of Excellence for biogas in the upcoming years. As a reaction to that, in December 2010, an action plan was worked out by the regional government together with municipalities, the county administrative board of Scania, universities and private companies in order to concretize specific actions to reach these goals and to form a basis for improved co-operation between actors in the industry. Although the action plan was worked out in collaboration with private companies and research organizations, the regional government played a major role in its development. As such, the action plan is in line with the decision on fossil free public transport taken in 2007, and can be seen as further signal providing legitimacy concerning the future support or biogas related activities in the region in the future. The effect of the legitimacy and market creation on the industry becomes evident by the fact that increasingly also private actors enter the industry and that the industry is diversifying in terms of markets. Whereas in 2007 the public transport was almost the only – and still is the dominant – commercial demander of biogas, the industry is diversifying in terms of demand; for example, as bio fuel, biogas becomes increasingly accepted also among private vehicle drivers in the region.

Discussion and conclusions

The above analysis aimed at unpacking the evolutionary process that has led to the emergence of the biogas industry in the region of Scania in southern Sweden. It intended to bring to light to what extent territory-specific institutions have mattered for its emergence – and in particular, to reveal how policy interventions can work actively in favour of new regional economic development paths, and by implication, steer transitions.

As identified in the analysis, the emergence of the biogas industry in Scania gained momentum through the announcement of the national KLIMP programme. By targeting local initiatives for energy efficiency and a reduction of greenhouse gasses, it provided legitimacy for technological change, while at the same time influencing actor's expectations, guiding their direction of search and creating incentives for further actors to enter the TIS. Yet, it has to be emphasized that KLIMP did not target industry emergence as such; rather, industry emergence should be seen as an implication and consequence of the programme as it provided a common orientation to previously existent activities (i.e. activities targeting natural gas and increasingly also biogas). The provision of legitimacy through policy interventions (i.e. KLIMP) led subsequently to an arising need for increased knowledge development and diffusion with regard to biogas technologies among actors, becoming apparent in the foundation of a network and support organisation for biogas (Biogas Syd). This need can be seen as a result of the preceding policy interventions, yet this time increasingly driven by private actors as a reaction to the legitimacy provided by the state towards (local) public authorities. Decisive for the further development of the emerging biogas industry in Scania were the subsequent political decisions taken in the region, i.e. by the county itself. By appointing biogas as a crucial fuel with future prospect in the regional public transport system, the regional authorities were tying up to the technological trajectory set by the preceding KLIMP programme and became active in supporting another TIS function, namely market formation. This can be seen as a crucial step for the commercialisation of a new technology and product as it provides further legitimacy, entrepreneurial expectation and guidance of the search for the actors.

It is important to note, however, that the success of the KLIMP applications from Scania, and as such the success of KLIMP in steering the development along a new technological path, was achieved due to specific prerequisites such as infrastructures, attitudes and competences existing in the region prior to the programme (i.e. the natural gas grid and experiences with natural gas busses; the collection of organic waste; the development of upgrading technologies in the region). At later stages of industry development, the political decisions taken in Scania, thus implying the authority of regional policy makers to take decisions on the innovation system, were of high importance for the biogas industry. Moreover, the existence of (related) industries producing organic waste (i.e. the availability of resources for the biogas production) was an important factor for the industry to form in Scania.

As such and referring to the discussion on industry emergence in evolutionary economic geography, the illustrated case does not support the argument of industry emergence being a random phenomenon, nor can industry emergence be exclusively explained by firm-level routines. Rather, the analysis reveals that the co-evolution of technology, industry dynamics and institutions (such as policy interventions) is important to consider when studying processes of (cleantech) industry emergence and evolution. By way of concluding, we argue that in the case of the biogas industry in Scania institutions have created functions in the innovation system over time. The functions started to interact with one another and created path-dependencies and stability. As such, Scania can be seen as a region possessing a critical amount of TIS functions working in favour of the biogas industry.

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Energy transition at the regional scale: An empirical investigation of development dynamics

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Abstract

Until recently, research (in social sciences) has explored the topic of energy transition mainly on a national scale. Although transition processes appear to be shaped to a significant extent on the regional level, there is still little research about regional transition processes. This paper addresses the dynamics of regional energy transitions by developing a heuristic model of these processes. Drawing on the regional innovation systems approach and its institutional perspective, this paper suggests three phases of regional energy transition: initiation, expansion, and consolidation. In the initiation phase, single actors start to experiment with socio-technical alternatives to the current energy regime(s). In the expansion phase, a rising number of actors get involved in a growing number of projects, and collaborations span over different social sub-systems. Finally, in the consolidation phase, the alternative practices are progressively stabilized by a new emerging institutional arrangement. In this paper, we present empirical insights from case studies on the regional energy transition in two German cities – Emden and Bottrop – to illustrate this model. Our data indicates interesting similarities between the two case studies, but also some differences that open up a future research agenda on phases of energy transformation processes.

Introduction

Energy transition entails multiple processes of change. Alternative socio-technological possibilities occur, new actors get involved, and new institutional rules emerge. These processes take place at multiple geographical scales, whereby the debate has mainly been concerned with the national level. The regional scale appears to play a crucial role for transition processes. For instance, more than 4,000 municipalities and regions have signed up the Covenant of Mayors initiative, committing themselves to concrete targets, and citizen-based communities such as Transition Towns or Low Carbon Communities indicate strong local bottom-up dynamics for energy change.

Therefore, this paper suggests looking at energy transition at the regional level from an institutional perspective. The core aim is to provide a systematic picture of the occurring development dynamics and to describe the characteristics behind them. Thus, we develop a heuristic model encompassing three phases, initiation, expansion, and consolidation. This model draws on ideas from the regional innovation systems approach and theories of institutional change which help to systematically analyze regional energy transition processes (in an institutional perspective). Two empirical cases serve as an illustration and allow deriving first insights on the interplay between different institutional spheres as well as actors in the outlined phases. These cases are taken from a research project about energy transitions in small-scale regions and explore the transition processes in two medium-sized German cities: Bottrop and Emden. Emden is a harbor city in north-western Germany which has experienced a transition from its traditionally very strong shipbuilding industry towards the renewable energy sector. In the last few decades, an increasing number of local actors has become involved in renewable energy and energy efficiency activities. Bottrop's energy transition, in contrast, is strongly shaped by the winning of the *Innovation City* Award. More than hundred different transition projects are currently planned and implemented to realize the energetic transformation of a whole city zone, home to around 70.000 inhabitants. Although the cities display at first glance very different transition dynamics, we have found similar development patterns which follow the proposed sequence of initiation, expansion, and consolidation. Yet, our analysis also reveals significant empirical differences in regional transition processes. The paper ends with a discussion of these differences and a short outlook.

Energy transition and phases of energy transition

"Energy transition" is a topic which is mainly discussed at the level of nation states, both in the public debate and in the academic discourse. However, the small-scale regional level in the energy transformation is of particular importance (McCauley and Stephens, 2012; Geels, 2011). In order to be able to describe the occurring change processes in detail, we take small-scale regions as a starting point to gain an in-depth insight into the involved processes of re-organization. This is meant to complement the two prevailing debates, Technological Innovation Systems and the Multi-Level Perspective. Both remain relatively vague on the importance of specific places for energy transition (Truffer and Coenen, 2012; Coenen et al., 2010) and do not provide a detailed account of how spatial aspects are interrelated with the ongoing changes.

In order to fill this research gap, we suggest drawing upon Regional Innovation Systems (RIS) as a potential source of inspiration (Cooke et al., 1998). RIS are defined as systems "in which firms and other organizations are systematically engaged in interactive learning through an institutional milieu characterized by embeddedness" (Cooke et al., 1998: 1581). They are geographically concentrated and institutionally stabilized networks of socio-culturally embedded companies. The levels of analysis include institutions as rules of the game, political and business organizations as collective actors (Cooke et al., 1998), as well as individual actors (cf. also Asheim and Isaksen, 2002).

Drawing upon RIS to complement the so far prevailing theoretical approaches holds two key advantages, that of a systematic inclusion of a spatial focus and that of explicitly adopting an encompassing institutional perspective. First, the RIS concept holds the chance to consider space and spatially restricted areas as important contributors to (or laboratories of) energy transition. As energy change processes span multiple geographic scales (cf. Truffer et al., 2012), it is worthwhile to disentangle the roles of different spatial levels in this interrelated and complex process in order to improve our theoretical understanding and to derive more precise and applicatory policy instruments. The exact entity of analysis is thereby a question of definition for which the RIS approach provides a possible framework. The scope of the investigated "region" can be defined a priori and in accordance with the specificities of the analyzed case. If the aim is – as in the present paper – to reflect the role of small-scale regions in energy transition processes, it makes sense to define these regions relatively small, i.e. at NUTS 3 level or even smaller. In the cases to be presented below, we even move below that level and focus exclusively on the area of cities. Zooming in is hereby a means to increase the preciseness of the analysis. The higher levels which undoubtedly interfere with the ongoing processes in small-scale regions are regarded as external factors that are not the main concern of our analysis.

Second, using elements of the RIS analysis to look at regional energy transition gives way to a systematic and encompassing institutional perspective. Institutions are at the center of the RIS approach as they are regarded as the elements that make interaction reliable (Martin, 2005). The institutional framework hence provides the spectrum of possibilities, defines easily accessible and non-feasible options, and acts as the backbone for interaction, knowledge exchange, and learning (Lundvall, 1992; Edquist, 2005). Organizations and individuals contribute to the formation of institutions and are hence also included in the analysis. In order to acknowledge the breadth of possibly relevant context factors, RIS are not restricted to directly innovation-related activities, but also include factors influencing innovation indirectly such as the economic structure in general, the education system, and political initiatives. Such a perspective implies that five subsystems are commonly investigated (Mattes, 2010; Heidenreich et al., 2012; Kuhlmann, 2001): the *scientific subsystem* (made up by science and education), the *industrial subsystem* (consisting of companies which compete, cooperate or supply (with) each other), the *political subsystem* (i.e. municipalities, regional administration, political parties and related actors), *intermediaries* (mainly referring to labor unions and chambers of commerce), and the *financial subsystem* (related to funding schemes, venture capital and banks). Moreover, the interaction between these subsystems and the resulting processes of renewal and change are part of the analysis. This gives way to a particularly encompassing perspective that is not biased towards a certain institutional sphere.

In this paper, our particular focus is on how this institutional setting changes to accommodate energy change. We are thereby suggesting three ideal-typical phases of energy transition, the initiation phase, the expansion phase, and the consolidation phase. In order to understand the ongoing change processes, we briefly address institutional change processes in general before deriving the three mentioned phases of energy transition.

In general, institutions are stabilized via path dependencies and "constant causes" (Thelen, 2008). However, institutions are not only means of stabilization and uncertainty reduction, but can be themselves subject to (mostly incremental) change (Streeck and Thelen, 2005; Mahoney and Thelen, 2010). In a broad understanding of change, these incremental processes can be called "institutional learning". Energy transition can be regarded as such a process of incremental change. It is important to note that, despite the occurring processes of mutual adaptation, societal structures are never settled for good, but ambiguities remain, and frictions between different players can persist for long periods of time (Streeck and Thelen, 2005).

For a more nuanced understanding of how institutional change processes take place, we draw upon the model suggested by Tushman and Rosenkopf (1992). In their description of processes of technological evolution, they differentiate between the three stages of variation, selection, and retention. In the widest sense, one can regard energy transition as such a process of social and organizational change in which random events, direct action and organizational interaction jointly lead to an adapted institutional framework (cf. Tushman and Rosenkopf, 1992). First, in the phase of variation, technological discontinuities occur and new technological possibilities emerge. In the phase of selection, various constellations co-exist before one specific path starts to dominate. This path is institutionalized in the retention phase, and a period of temporary stability can emerge. At any time, the process can be triggered anew and the next circle of technological change starts (Tushman and Rosenkopf, 1992).

We will now interpret this model for processes of energy transition. The core idea is that what we commonly term as "energy transition" is an ongoing process of change in which again and again new socio-technical possibilities emerge, are being institutionalized, and result in temporary equilibriums – before these are questioned again and give way to new alternatives.

First, we define variation as the initiation of (new paths of) energy transition. Besides the prevailing traditional socio-technical constellations, new possibilities are considered and carefully experimented with. As there is no fully established system yet, the different institutional spheres remain partly separated from each other, and individual, small-scale projects dominate. This initiation of change and rupture can occur in any subsystem, but it is not dependent upon a strong or stable interaction between various subsystems. Instead, variation describes individual, small and cautious steps towards change.

The expansion phase is closely related to what Tushman and Rosenkopf (1992) term selection. Hereby, socio-technical alternatives spread, and the institutional order starts to adapt itself accordingly. In the terminology of the MLP approach, this would be the emergence of niches, i.e. of new socio-technical possibilities that coexist with the so-far dominant order. There is a rising number of actors, activities, and collaborations that experiment with different aspects of the new socio-technical possibilities. Based on this choice of projects, actors, and initiatives in the region, these are slowly combined or adapted to each other in order to exploit potential synergies. This goes along with an increasing selection and sorting of possibilities. Actors and subsystems are more closely interconnected, and the first stable coalitions are built. This also goes along with a more dominant, visible and accepted position of new socio-technical perspectives in the region.

Third, we refer to retention as consolidation phase. The newly established routines and institutions are being stabilized and put onto more durable ground. Long term planning, the fixing of long term objectives, and stronger coordination of the activities can contribute to stabilization. The new socio-technical possibilities cease to belong to a mere niche and are – at least in a defined area or region – slowly turning into the dominant regime. The resulting order is temporary and fragile, but this phase is characterized by the development of a new prevailing institutional arrangement which brings along at least temporary stability.

The outlined characteristics of the three phases are summarized in table 1. It has to be stressed that the differentiation between the phases is of course ideal-typical and serves for a better theoretical understanding rather than representing a precise empirical classification.

Table 1: Phases of energy transition and their core characteristics

Initiation (variation)	- Socio-technical alternatives complement prevailing old system - Selective, individual activities in isolated subsystems - Individual initiatives prevail - Personal relations are central
Expansion (selection)	- Old system is increasingly being modified (or questioned) - More activities - More involved actors - More interaction and cooperation between actors and subsystems - More visibility of socio-technical alternatives - Conflicts and frictions in choice between several alternatives (new/old and which new option?) - Definition of adequate procedures
Consolidation (retention)	- Stabilization of the new socio-technical constellations - (At least temporary) durability of established paths - Attempts of long-term planning - More concertized coordination and bundling of activities - Emergence of shared rules and perceptions

Source: own representation.

To sum up, the three phases of variation – selection – retention form an ongoing process of dynamic change which may be transferrable to energy transitions at the small-scale regional level. This process of change is a combination of planned, strategic, coincidental or unplanned emergent elements. Path dependencies are thereby closely interwoven with organizational and individual aims. The complex regional institutional arrangement hence rearranges itself, forming a new temporary equilibrium. This change may originate in single subsystems, but is stabilized and maintained in the complex interaction between several or all relevant subsystems. Energy transition is, in this perspective, a complex process of institutionalization.

In the following, we will illustrate this process empirically and show how the suggested framework can help to understand energy transition at the regional scale more precisely. It is crucial to stress that we are not considering both empirical city-regions as RIS in a strict sense. Instead, we use elements of RIS and institutional approaches to show how the relevant regional structures change.

Methodology

We follow a qualitative approach based on semi-structured expert interviews and conducted interviews in two German regions, Bottrop and Emden. In each case, more than 30 interviews covered the representatives of the different relevant institutional areas (politics, industry, science etc.). The duration of interviews ranged from around 60 up to 145 minutes. All interviews were based on a common project interview guideline which broadly defined conversation contents. The conversations were recorded and afterwards transcribed for the data analysis. Using the software MAXQDA, the produced interview transcriptions were subsequently structured along analytical categories (“codes”), allowing for a systematic and encompassing analysis of selected research issues.

Emden’s energy transition in three phases

Emden is a small harbor city of around 52.000 habitants in north-west Germany. This city’s economy is marked by the shipping industry, a big manufacturing site of a German car builder and increasingly by the wind energy industry. In the last decades, Emden’s economy has experienced a transformation from its historically very strong shipbuilding sector towards the wind energy sector. With the decline of the ship industry several wind energy businesses have emerged. Moreover, the city has developed an increasing focus on the topic of energy transition, as the following description of the three phases of Emden’s energy transition shows.

Initiation phase

The initiation of Emden’s energy transition is characterized by *loose projects of single actors* and *little cooperation between different subsystems*. The first project which marks the beginning of Emden’s energy transition is the installation of a wind mill at the local water works in 1987. This project is essentially shaped by the mayor who persuades the CEO of the municipal utility company to supply a water pump at the water works with wind energy. Shortly after the realization of this project, the CEO of the public utility company retires and gets substituted by a CEO who shows a strong interest in renewable energies. The new CEO re-orientates the public utility company towards renewable energy sources and energy efficiency. This reorientation leads to the installation of a small wind farm and awareness raising campaigns to encourage citizens to save energy. However, at that time these projects are not meant to substitute but to *complement the prevailing energy system*. A substantial change of the system is so far not intended. Instead, these small-scale projects constitute a way of *experimenting with new solutions and technologies*. These experiments are backed by local politics, and in particular the mayor of the city, who gets convinced by the new CEO to support them.

For the moment, the attempts to create a local energy transition remain mainly restricted to the public utility company and, perhaps to a minor degree, to actors in local politics and the city administration who provide back-up for the projects of the public utility company. In contrast, actors from the other subsystems show little interest in the local energy transition. Some rather *fragmented activities* take place in the economic subsystem and among citizens. However, these activities remain selective and isolated from each other. Apart from the interaction between the CEO of the public utility company and a few actors from the political subsystem and the city administration, there is *little interaction between local subsystems* in the energy sector. It is mostly *single actors* such as the new CEO in these subsystems who strive for changes. Another important actor who assumes a progressively leading role in these changes is a former employee of the public utility company. He starts up a business for the planning of wind and solar farms and becomes an entrepreneur for the local energy transition. This entrepreneur maintains a close relationship with the CEO of the public utility company, the mayor, and the city administration. A strong cooperation evolves between these actors who become the key actors for the initiation of Emden's energy transition. Their "personal contacts are very, very important" (interviewee D) for initiating change in Emden, as one interviewee notices. Thus, their close exchange of ideas and support enables them to implement different projects (e.g. the energy exhibition "Emder Energie Tage", solar panels on bunkers) and increases the public visibility of the local energy transition. Given this development, other actors become interested in the energy transition and begin to conceive their own transition projects, giving rise to an expansion phase.

Expansion phase

A rising number of projects, actors, and collaborations marks the expansion phase. Actors from *different subsystems* start to relate their activity to the energy transition and generate transition projects. The *rising involvement of local actors* is not only related to the increased public attention to the subject but also to the perception of potential gains from the local energy transition. Thus, political actors realize that they can generate public recognition, employment, and finally gain votes by pushing energy-related projects. Similarly, businesses realize that they can generate profits by exploiting new business opportunities related to energy transition. For instance, businesses located in Emden's harbor discover renewable energy, in particular offshore wind energy, as a promising business field. Hit by downturn in its traditional business area, a local shipbuilding company re-orientates its business activities towards the renewable energy sector and starts to construct wind mill towers and platforms for offshore wind farms. Other wind energy businesses emerge in the harbor, while longstanding companies seek to integrate the new business opportunities into their strategies (e.g. transportation of employees and material to offshore wind farms). In total, the energy transition becomes increasingly important for the local economy, as an interviewee acknowledges: "Renewable energies are of high significance now, because companies in the region generate a lot of added value in this economic sector." (interviewee A) Likewise, other companies increasingly relate their activities to energy transition. For instance, local banks start offering specific loans to home owners for energy efficiency refurbishments and renewable energy installations (e.g. solar panels). Due to its rising importance for the local economy, the local chamber of commerce and other intermediaries develop a focus on energy transition. Also beyond the industrial subsystem, energy transition assumes a rising importance. The local university creates a degree in "energy efficiency", and becomes a local knowledge provider for transition projects (e.g. wind power to gas applications for the public utility company). Last but not least, actors that were already involved in the initiation phase – such as the public utility company, the city administration, the entrepreneur and his business – intensify their involvement. In total, we have found a rising interest in the local energy transition which makes *more local actors to engage in the energy transition*.

Due to the rising involvement of local actors in the energy transition, a *rising number of transition projects* are being carried out. The local energy transition spreads and becomes increasingly palpable. Large wind farms emerge in the outskirts of Emden, solar panels are installed in the city of Emden, public buildings are refurbished to low energy, and education programs and energy saving competitions at schools as well as programs to increase the share of cycling and public transportation are being implemented. Many of these projects are only feasible due to the *collaboration of actors from different subsystems*. The energy education program at schools is, for instance, based on the cooperation of the city administration, local schools, the public utility company, and the local ecology center. Another example is the construction of what was at that moment Europe`s biggest wind farm. Many other actors such as other regional businesses, private investors, politicians, and the city administration contribute with their specific competences to the success of this project. In this context, further collaborations between local actors from different subsystems evolve and existing collaborations are being strengthened. The local energy transition is less and less based on the efforts of single actors but on collaborative efforts which develop in vast social networks that span over different subsystems. Due to the general acknowledgement of the importance of the energy transition for the city, the collaboration of local actors becomes more likely: "It has been recognized in the whole region that renewable energies are very, very important. And therefore the cooperation is of high quality and straightforward. One does not have to convince the people of the importance of the issue, they already have recognized its importance so that working together is quite uncomplicated." (interviewee B)

However, this phase is not only marked by collaboration but also by *conflicts* with the "old" energy regime. A Danish power company plans to construct a coal power plant in Emden. These plans produce a strong rejection in the population and among the key actors of the local energy transition who subsequently mobilize against the construction of the coal power plant. In the end, the power company renounces from its plans. In this case, the energy transition appears to have outplayed the "old" energy regime. The victory of this power struggle could be a *first sign of the replacement of the "old" energy system* by new technologies and ways of thinking energy. Hence, one interviewee already states: "Renewable energy is positioned in this region quite firmly." (interviewee C)

In total, besides conflicts with the "old" regime, one can observe a rising number of activities, actors, and collaborations which lead to a *rising public presence and visibility of energy transition* which further spurs actors to engage in and initiate new transition projects. The high quantity of projects, actors, and collaborations raises the question of how the efforts can be bundled in an efficient way and how adequate standards of action can be established. These challenges are related to the consolidation phase. Although Emden appears to move still in the expansion phase today, there are first indicators for a transition towards a consolidation phase which will be addressed in the following.

Towards consolidation?

Despite the fact that Emden is still moving in the expansion phase, there are also some developments that can be attributed to the consolidation phase. The consolidation phase is characterized by the fact that the *new energy regime gets stabilized* and is put on a more durable ground. In Emden, such a stabilization process is carried out particularly through the *fixing of long run objectives*. Thus, the public utility company has set the objective to cover 100% of Emden's energy consumption with renewable energy until 2030. Further, politics and city administration have agreed with other local actors on a plan to cut 50% of the total CO2 emissions until 2020 (as compared to 1990 levels). Another feature that marks the consolidation phase is *long term planning* *and coordination*. Thus, long term objectives are being formulated, and these imply plans and joined measures of different actors in the city to significantly improve energy efficiency and expand the proportion of renewable energies in the energy consumption. Finally, in order to put the energy transition on a more stable and durable ground, the coordination of actors and activities from different subsystem is set onto more durable grounds. There are different efforts to formalize and *improve the coordination of local actors*. For instance, a climate manager has been employed by the city with the objective to network and coordinate local actors. At the same time, different intermediary organizations try to spur the exchange of knowledge concerning the local energy transition between actors and to integrate more actors into these activities. In sum, first developments into the direction of a stabilization of the local energy transition are visible. These developments are particularly marked by the fixing of long term objectives and planning in order to implement and stabilize the new energy regime.

Conclusions from the case of Emden

First initiatives in the energy transition are undertaken from the late 1980s onwards. These initiatives draw back to the commitment of single actors such as the mayor, the CEO, an entrepreneur, and employees from the city administration. Their informal and close contact helps them to implement these projects and render local energy transition into a publicly visible subject. Due to these activities and the risen visibility, more and more actors become aware of the energy transition and realize its profitability. The expansion phase is marked by an increased number of actors, projects, and collaborations engaging in the local transition. Conflicts with the "old" energy regime emerge and are for the moment decided in favor of the energy transition. Moreover, efforts to put the transition onto a more stable ground are undertaken. Long term objectives, involving a radical reduction of CO_2 emissions and a vast increase in the proportion of renewable energy, and the improvement of the coordination between local actors contribute to the consolidation of a new energy configuration.

Bottrop's energy transition in three phases

Bottrop's energy transition has to be analyzed from the background of its *heritage in coal exploitation*. Despite the economic downturn of coal and steel industry in the Ruhr region, even today around 5.000 people remain employed in the last coal mine in operation (closing in 2018), and, according to estimations of interviewed experts, another 2.000 jobs depend indirectly on coal extraction. Bottrop's energy transition is not a history of radical opposition to this coal heritage, but rather one of a stepwise reorientation of energy-related activities. In the following, we will provide empirical elements to underpin the three ideal type phases of initiation, expansion, and consolidation for the case of Bottrop.

Initiation

The beginning of Bottrop's energy transition can be traced back to the mid-90ies when the city administration adopts its first energy conservation measures and singular private actors start pioneering renewable energy projects. Thus, the city launches a municipal energy management, appoints an energy and climate manager (1993) and conceives a local energy plan (1997), making climate and energy policies a "guiding principle" (interviewee A) of Bottrop's policies. As a result from this commitment, Bottrop succeeds to reduce the energy consumption in public buildings by around 40% (heating), respectively 35% (electricity) from 1993 to 2008 (Stadt Bottrop 2010). In recognition for its activities, the city is awarded European Energy Silver (2005) and, later, the Gold standard (2010).

In addition to this strong commitment of the city administration, some *civil society and private company activities rise*. For instance, farmers in the more rural part of Bottrop, Krichhellen, install wind turbines and massively invested in PV, making Bottrop the city with the largest installed PV capacity per citizen in the Ruhr area (interviewee D); a new settlement is provided entirely with a geothermal heating system; a community of entrepreneurs in an industry zone joins for a research project on potential measures to become a Zero Emission Park; and, finally, since 2007 the public water management company Emschergenossenschaft has been transforming sewage gas to hydrogen, which covers the energy demand of Bottrop's purification plant and fuels some hydrogen buses.

In contrast, the political subsystem plays a surprisingly passive role in this phase. Several interviewees describe the most influential local parties as "willing enablers" of the local energy transformation. Without strong ambition to shape changes themselves, the politicians provide a framework of "stability for action" (*Planungssicherheit)* through their decisions, enabling the administration and private actors to push forward their projects.

The initiation phase is hence mainly shaped by *a few actors from selected subsystems*, namely the city administration and, to some degree, by civil society and local businesses. These actors punctually interact, but are still *rather loosely coupled*. For instance, the private projects are largely realized in autonomy from the city administration. However, according to several interviewed representatives from such private initiatives, the administration supports these projects with advice and practical assistance or, in the case of the Zero Emission Park, even gives the initial impetus.

According to the vast majority of interviewees, Bottrop's initial dynamics can, to a large degree, be explained by *the enthusiastic personal commitment* of leading staff members of the city department, most importantly the current mayor, and *strong, long-lasting informal personal relationships between city departments*, namely the Departments for Urban Planning, Urban Renewal, Environment and Greenery, and Economic Development. Thus, a *"dense communication structure"* (interviewee B) and *"short ways"* (interviewee A) beyond formalized administration rules have created a solution-oriented working climate where colleagues *"complement each other and do not see each other as competitors"* and *"think in similar directions"* (interviewee C). With the successful application as Innovation City in 2010, the local actor system changes and the expansion phase starts.

Expansion

Bottrop wins a competition between 14 participating cities that respond to a call launched by the industry association *Initiativkreis Ruhr*. In its application, Bottrop suggests the energetic transformation of a complete city area, home to around 70.000 inhabitants, business, and industry zones. It sets itself the extremely ambitious objective to cut its CO2 emissions by 50% until 2020 (on a 2010 level).

The winning of the IC Award brings about *a multiplication of the involved actors and activities*. Over 100 single projects have been planned or initiated. They cover the areas of urban planning, housing, industry, tertiary buildings, and transport. New actors have entered the floor, mainly numerous industry companies as members of the Initiativkreis Ruhr, but also research institutions, craft businesses, banks, or external political players. The most powerful new player, however, is set up with the intermediary organization *Innovation City GmbH* (Limited Liability Company). This public-private body counts on staff from both Initiativkreis Ruhr and an associated company, and is in charge of coordinating and steering the transformation processes. With its specific unit ZIB (Centre for Information and Advice), it also hosts an important access point for residents.

This new, more complex actor constellation lead to a situation of uncertainty, where *differing perspectives on the future development path of Bottrop and diverging interests meet*. A process of *selection* is ongoing. There are several examples of contradictory paradigmatic orientations, but two of them are particularly crucial. A first recurring, sometimes very explicit, sometimes rather subtle conflict is between a techno-economic approach on the one hand and a more comprehensive urban planning perspective on the other hand. Most of the economic actors seem to share a *Green New Deal* vision of the IC project, arguing that efficient and "greener" technology will enable our societies to cut carbon emissions. In contrast, the alternative, holistic urban planning perspective considers technology rather as part of a complex socio-technical system that needs to be integrated into people's life worlds and complemented by intelligent, flexible urban planning, and people-centered governance. A second inherent conflict spans between the ambition to develop somehow elitist, lighthouse innovation projects that create a high (even international) visibility for its stakeholders, and the need to achieve large scale, but more "trivial" changes (in particular in terms of building retrofitting) with existing affordable and pragmatic solutions to the benefit of the residents. These paradigmatic cleavages also go along with a slightly *increased politicization*. The marginalized small opposition parties have become more critical towards the IC project, in particular with regard to the perceived industry-orientation and the low financial underpinning, and raise their voice outside the formalized decision making bodies. Their strong media presence has contributed to a strong pressure on the new IC GmbH to deliver quick results.

Towards consolidation?

Despite the described paradigmatic tensions, Bottrop's local energy transition system seems to be partially *stabilized.* First, this is due to *redefined responsibilities and roles as well as new forms of coordination*. Several interviewees recall an initial phase of high uncertainty after the creation of the IC GmbH that some describe as "chaotic". Within the city administration, some key staff members are being appointed as *Handlungsfeldkoordinatoren* (action field coordinators), which is an entirely new position beyond the classical administration hierarchy. Their role is to combine necessary expertise from different departments to respond to defined strategic IC action fields. Similarly, at the IC GmbH some staff members are given the responsibility to act as key entry points for specific stakeholders (e.g. for companies, research or craftsmen). With *the Friday project round table*, a new central place of coordination is introduced assembling every week all important decision makers and technical staff involved in the ongoing projects. All important day-to-day decisions are made by this institution. Finally, a number of *committees* with mainly consultative function are launched.

Second, there is some evidence for the establishment *of shared rules of appropriate action*. The most important evolution is the creation of shared standards of qualification, advice services, and tariffing systems among crafts businesses that are organized in the "IC partner network". All members of this partner network commit themselves to certain quality standards specific to energy efficient retrofitting which have to be acquired in additional vocational training courses. Furthermore, an ad-hoc assessment tool has been conceived by the Fraunhofer Umsicht research institute in collaboration with the IC GmbH. Based on a list of indicators on four main analytical categories, it examines the eligibility of any new project suggested as part of IC. It hence defines certain quality standards that will have to be taken into account by all organizations willing to contribute to the IC project.

The recent decision to mandate a consortium of external consultancies, led by the internationally renowned planning office Albert Speer Architects, to conceive a *master plan* by the end of 2013 can be interpreted as a further step towards stabilization. The master plan shall define an overarching road map of action, combining insights from diverse fields of expertise – engineering, urban planning, communication, governance etc. It is expected to provide *a long-term action framework* line that binds all involved actors with their projects on a shared story line of Bottrop's energy transformation. It may also help to resolve the existing paradigmatic tensions.

Conclusions from the case of Bottrop

The beginning of Bottrop's energy transition can be traced back to mid-90ies when the city administration starts its first energy saving activities for municipal buildings. Also the first pioneering citizen or company-driven renewable energy projects are initiated at that time. These activities are continuously being developed and put on a more solid ground with the appointment of a climate manager, the approval of a climate action plan, and the participation in the European Energy Award program. Historically, *this Initiation phase* ends with the successful application as *Innovation City* which gives rise to a period of *expansion*. The number of involved actors has multiplied and more than 100 projects are being planned or implemented. This more complex actor constellation has led to a situation where diverging interests and paradigmatic orientations compete in a process of *selection*. However, our findings also indicate that a new playing field has emerged where role definitions and responsibilities, forms of coordination between actors, and rules of appropriate action have been (re)arranged. These developments and the upcoming master plan may be elements of a *consolidation phase*.

Comparison of transition phases in Bottrop and Emden

In the previous sections, we have described the energy transformation processes of two German cities that both share a strong industrial heritage – Emden in shipbuilding and Bottrop in coal exploitation. Both cities faced difficulties when those industries experienced an economic decline and their activities in the energy field were part of rebuilding the cities' identities. Our findings show some interesting similarities, but also differences, in their energy transition paths. In the following, we will discuss these characteristics along the three phases that have structured this paper.

Initiation phase

The initiation phase is in both cases marked by the commitment of single actors who launch first transition projects such as a first wind farm in Emden and the municipal energy management in Bottrop. In Bottrop, the city administration, the mayor, and a few farmers and entrepreneurs engage in initiating the local energy transition whereas in Emden, the new CEO of the public utility company, the mayor, an entrepreneur, and some city administration employees are the crucial actors in this initiation phase. In both cities, the initiation of the activities is related only to a few subsystems and actors whereas other social subsystems and actors seem to remain temporarily rather remote from the transition activities. It is the enthusiastic commitment of single actors which pushes the local initiation of the energy transitions. Many of the projects benefit from the close and informal relationships between these actors. Their informal networks spur the exchange of knowledge and thereby facilitate the implementation of projects that experiment with new energy concepts in these cities. In this phase, actors do not conceive activities in explicit opposition to the dominant energy configuration, but seek to complement the existing energy configuration. However, with the success of the first projects and the rising commitment of local actors, the visibility of the local energy transition rises, and more actors from different subsystems start to become interested in energy-related topics. These developments point to the beginning of the expansion phase. While the transition into this new phase is continuous in Emden, in the case of Bottrop, it is particularly marked by the winning of the Innovation City Award.

Expansion phase

Based on the ground that has been laid by a few actors in Emden and Bottrop, both cities experience a phase of expansion that is characterized by a growing number of involved actors, an increasing number of activities, and more interaction between the actors. In Bottrop, this expansion phase has its historical landmark, which is the winning of the Innovation City Award (2010). A new powerful actor is set up with the Innovation City GmbH and numerous regional major industry companies, research institutions, banks, and housing companies have engaged in more than 100 planned or ongoing projects. This more complex actor system has brought about a variety of interests and paradigmatic perspectives that has led to a number of sometimes explicit, sometimes rather subtle tensions with regard to the “good” transformation path of the city. Emden’s expansion phase is characterized by the growing recognition that energy efficiency and renewable energy sources form a strategically important action field. Hence, some previously rather marginal actors such as the local university have entered the stage with own activities, in particular in the field of wind energy, and have contributed to a higher relevance of energy topics in the public discourse. The projects in Emden cover a wider scope of activities and have become more complex, involving also an increased need for coordination between actors. The structures of an alternative local energy regime have also been strengthened by the fierce civic opposition against plans to build a new coal power plant. This illustrates the most interesting difference between the two cases: while Emden’s actors seem to conceive their activities as a clear alternative to the “old” system of energy provision and consumption, the ongoing debates in Bottrop rather deal with the appropriate *way* to achieve a low-carbon reorganization of the city.

Consolidation phase

Efforts to stabilize the new energy configuration characterize the consolidation phase. These efforts become manifest in both cities in form of long term planning and setting long run goals. In the case of Bottrop, a master plan is currently designed which will define a road map for the local energy transition. In Emden, the city administration, the public utility company, and other local actors have agreed on a very ambitious goal for CO_2 emissions reductions and aim to cover the entire local energy demand with renewable energies until 2030. The activities are also stabilized by an improved coordination between local actors. After a rather difficult start, roles and responsibilities have been rearranged in Bottrop’s Innovation City, in particular through a weekly project round table.

Furthermore, Bottrop displays elements of shared formalized rules, most importantly an ad-hoc assessment tool and qualification standards for craft businesses. In Emden, the recently employed climate manager and network organizations seek to improve the interaction of local actors and bundle their transition activities. Although the transition activities are put on a more stable basis through ambitious long-term goals and an improved coordination, it is not clear to what degree shared understandings of the energy transition have emerged in the two cities. This becomes particularly evident in Bottrop where one can witness paradigmatic cleavages concerning the "best ways" of implementing the energy transition. Yet, the development of shared understandings may be an important factor for a long run consolidation of local energy transitions.

Discussion and conclusions

As the comparative analysis shows, the occurring processes of energy transition are complex, and the suggested model can of course only grasp them partly. However, the detailed account of the phases illustrates that energy transition is not a smooth process, but takes place in an intense interaction between multiple actors and subsystems. The adopted institutional perspective helps to acknowledge that not all subsystems are of equal importance in every region, and it also shows that this importance varies and changes in the course of the transition process. While the initiation phase is dominated by singular actors in both cases, expansion and consolidation are marked by a more nuanced interplay between actors and subsystems. The assumed roles are gradually institutionalized and stabilized, and patterns of interaction turn into increasingly reliable structures. While these general processes are comparable between the cases, the exact development paths the two cities take differ significantly.

The classification of the cases into different phases is not at all trivial and straight-forward. As overlaps tend to occur in empirical evidence for any ideal-typical distinction, our data indicates that specific city-regions display elements of several phases in parallel.Bottrop's change processes can be considered as steered transformation that entails rapid restructuration processes (triggered by the Innovation City Award), while in Emden the phases overlap more strongly and proceed more slowly and cautiously. Even though we have only presented evidence from two cases, it is hence obvious that there is not one best way to implement change, but that there are different paths with a wide spectrum of possibilities.

These differences are also mirrored in the role different institutional subsystems and actors assume with regard to the outlined change processes. In Bottrop, the Innovation City GmbH assumes a dominant role in coordinating and concertizing energy-related activities. In Emden, in contrast, such a central coordination organization is still missing, leaving more room for individual commitment and flexible coordination. Moreover, the leading role is not clearly assigned to one single actor in Emden, but is rather distributed among several involved actors from different subsystems.

In this article, we have suggested a heuristic model which can contribute to a better understanding of how local energy change occurs. Based on an encompassing institutional perspective, we have distinguished the three phases of initiation, expansion, and consolidation, thus shedding new light onto different steps in the evolution of new socio-technical energy regimes. As Tushman and Rosenkopf (1992) outline themselves, the equilibrium reached in their retention phase (consolidation) is thereby only of temporary stability. Instead of looking at the model as a three-stage linear procedure, it should hence be regarded as a circular process, whereby the evolution spirals from one stage to the next in a never-ending process. And even though this is generally regarded as a path-dependent process (Pierson, 2000), path deviations are of course likewise possible.

The core contribution of this article hence lies in allowing a structured empirical analysis of energy transition at a regional scale. In order to grant this, we have suggested a framework for analysis that brings in elements so far not prominent in the transition debate, an institutional perspective based on RIS and evolutionary change. While the ideal-typical character of the model is evident and thus has to be interpreted with caution, even our limited empirical data revealed some interesting structural insights into the occurring change processes. Further research may apply the model on a larger scale to confirm or adjust the outlined phases and to define more precisely what exactly lies behind the outlined processes of energy transition on a regional scale. Moreover, it would also be worthwhile to adopt a multi-layer approach which takes into account more systematically not only the processes at the regional scale, but also their interplay with national and international regulation and action.

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Submission 194

Technology Innovation System Analysis of the Solar Water Heater Industry in South Africa

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Key words; TIS; systems thinking, causal loop diagrams

Abstract

One of the key challenges that developing countries face is the provision of clean and sustainable energy. The large scale usage of renewable energy sources and related conversion technology are necessary conditions for sustainable development. One such technology that has the potential to address energy and environmental issues in developing countries is the solar water heater (SWH) technology. In South Africa, this technology has experienced strong growth in the past 5 years; however a systematic analysis of its success has not been proposed. The technology innovation system approach (TIS) has been utilised successfully to understand the process of technological innovation in many developed countries (Negro et al. 2007). This seemingly useful technique has not yet been applied in the South African context. The objective of this paper is to Apply the TIS framework to the SWH industry in South Africa with the aim of i) Understanding its evolution and identifying key dynamics and the corresponding structure that were instrumental to its success and ii) Explore whether motors of innovation can be depicted in the system theory language of CLDs. The study has helped identify the functional constellations that were prevalent during each of the 4 periods studied, described as motors of innovation. Four different 'motors of innovation' were identified during the period studied viz. '**Project Motor**' in the 1st, the '**Breakdown Motor**' during the 2nd episode, the '**Knowledge Building Motor**' in the 3rd episode and '**Market Motor**' in the 4th episode. This has demonstrated which of the functions ought to be fulfilled, in order that the TIS structure is aligned. The applicability of causal loop diagrams in depicting the dynamics of the system was also demonstrated.

1. Introduction

One of the key challenges that developing countries face is the provision of clean and sustainable energy. The large scale usage of renewable energy sources and related conversion technology are necessary conditions for sustainable development. One such technology that has the potential to address energy and environmental issues in developing countries is the solar water heater (SWH) technology. In South Africa, this technology has experienced strong growth in the past 5 years;

however a systematic analysis of its success has not been proposed. Insights from such a systematic analysis have the potential to inform and influence the policy direction of other renewable energy technologies that are still in the early stages of development. The technology innovation system approach (TIS) has been utilised successfully to understand the process of technological innovation in many developed countries (Negro et al. 2007).

Negro et al.(2008) note that despite the fact that the development, diffusion and application of renewable energy remains high on the agenda of most governments, it has proven difficult for it to replace sizeable quantities of fossil fuels, Hekkert et al. (2007) emphasise that there is a need to influence both the speed and direction of innovation around renewable energy technologies. Negro et al. (2008) note that many obstacles need to be overcome for the smooth diffusion of renewable energy technologies and that, due to different obstacles for different countries and technologies, more insight is needed on the process through which renewable energy technologies emerge and how they are able to achieve successful diffusion into society.

Alkemade et al. (2011) stress that socio-technical transitions are necessary for social sub-systems such as the energy sector to become sustainable. Socio-technical transitions, in which innovation is key, require development and diffusion of a wide range of technologies alongside the development of new institutions and social practices (Geels 2005). According to Markard & Truffer (2008) an improved understanding of these processes is important but demanding: important because of the consequences they have on their suppliers, producers, customers, policy makers and societies as a whole and demanding because of the complexity of innovation processes (*ibid*).

There are two broad approaches for analysing socio-technical transitions, namely the innovation system approach and the multi-level perspective (MLP), detailed in Alkemade et al. (2011). A detailed analysis of the 2 approaches has been done elsewhere (Alkemade et al., 2011) weighing the pros and cons of each of the approaches.

The technology innovation system (TIS) approach has been specifically used to analyse the success and failures in implementing renewable energy technologies in developed countries (S. Jacobsson 2004; Bergek et al. 2008; Negro et al. 2007; Negro et al. 2008; Suurs et al. ,2009). A TIS is defined as actors, the networks, the form, the institutions (rules) and technology that influences the development, diffusion and use of an emerging technology (Suurs & Hekkert 2009; Carlsson 2006) For developing countries, there is a scarcity of studies that have applied the innovation system approach for renewable energy technologies. Mondal et al., (2010) used the Sectoral Systems of Innovation approach popularised by Malerba (2005) to identify barriers that need to be overcome for a successful development of a renewable energy technology sector. Another study, which employs this concept, is Tanzanian based (Szogs & Wilson, 2008), their approach is somewhat surprising as they use the national system of innovation approach to investigate a specific technology ‘Biomass

Digestion Technology'. TIS has been recently applied some empirical studies in Brazilian sugar industry (Pellegrin et al., 2010).

The paper is structured as follows: Section 2 gives some notes on the technology innovation system literature and summarises the paper's objectives. Section 3 presents the methodology employed in the study. Section 4 presents an application of the framework to SWHs in South Africa, followed by a discussion in Section 5 and conclusions and recommendations for future studies in Section 6.

2. Notes on the Technology Innovation Approach

Technology innovation System (TIS) and its ability to bring about economic development has been studied for many decades. The traditional conceptualisation has been that of a linear development, which begins with basic research, then applied R&D which should then lead to production and diffusion (Suurs & Hekkert 2009; Godin, 2006). In contrast the TIS approach views technological change or innovation as a non-linear development that is constituted by many processes (Suurs et al., 2009) These processes need to happen in parallel and reinforce each other through feedback mechanisms. Besides as Arnold (2004) notes, system worlds need system evaluation.

Central to the TIS literature is the notion that most emerging technologies will pass through a so-called formative stage before they are subjected to a market environment (Jacobsson 2004). In this formative stage, actors are drawn in, networks amongst the actors are formed and institutions are designed and adjusted. According to Suurs et al. (2009), in a perfect world, the TIS would develop and expand its effect, thereby driving the emerging technology towards a stage of market diffusion. By studying key activities, also known as system functions, it is possible study the build-up of an emerging technology. There are widely agreed upon set of system functions (Hekkert et al., 2007; Bergek et al., 2008) In this study, the 7 functions as proposed by Hekkert et al. (2007), will be used. These are listed and briefly explained in Table 1 below:

Table 1: An overview of system functions

System functions	Descriptions
Entrepreneurial Activities [F1]	This function is associated with experimentation by entrepreneurs in translating new knowledge into innovation and business opportunities
Knowledge Development [F2]	This function encompasses learning of an emerging technology, it is generally classified into 'learning by searching' (R&D) and 'learning by doing' e.g. demonstration

	activity
Knowledge Diffusion [F3]	This function captures the knowledge shared amongst actors, usually facilitated by networks, this is usually termed 'learning by interacting' and 'learning by using' (e.g. pilot activity)
Guidance of Search [F4]	While F2 is about generating variety through R&D, this function refers to those activities that guide actors on which segment of the industry/technology to focus on and also channel the expectation of actors on the emerging technology in the right direction
Market Formation [F5]	This function talks to supporting an emerging technology, to create protected markets that do not compete with incumbent technologies
Resource mobilisations [F6]	This function deals with mobilisation of both capital and human resources
Advocacy Coalition [F7]	Here actors in an emerging technology organise themselves so that they can lobby for better conditions, this usually due to resistance from incumbent system to take to the new innovation

For any emerging technology to take off, the system functions need to reinforce each other over time resulting in virtuous cycles, these positive feedback loops point to the existence of cumulative causation (Suurs et al. 2009) On the other hand, (Hekkert et al. 2007) note that system functions may reinforce each other negatively resulting in vicious cycles. Different forms of cumulative causation exist as revealed in recent empirical studies (Negro et al., 2008; Suurs & Hekkert 2009; Negro et al., 2012) characterised by differing patterns of interacting functions and referred to as motors of innovation (e.g. Entrepreneurial motor that will be characterised by the dominant fulfilment of the entrepreneurial activity). There is a realisation that these motors are in fact reinforcing loops that can be well depicted by system theory's Causal Loop Diagrams (CLDs). There are currently no empirical studies that have attempted to represent the dynamics, and thus motors of innovation in the CLD language.

The objective of this paper is therefore to i) Apply the TIS framework to the SWH industry in South Africa with the aim of understanding its evolution and identifying key dynamics and the corresponding structure that were instrumental to its success and ii) Explore whether motors of innovation can be depicted in the system theory language of CLDs.

3. Methods

An event history analysis as developed by (Van de Ven 2005) and adapted by (M.P. Hekkert et al., 2007)forms the basis for our analysis. This approach allows for construction of a narrative that is able to concurrently identify structure and system functions fulfilment in the period analysed and is able to draw out the cumulative causation patterns, also known as motors of innovation. The method has been further modified to include causal loop diagrams (CLD). The steps taken are summarised below:

i) Data collection for the period 1978-2012
ii) A database was constructed listing events in a chronological order
iii) The events were then mapped to the system functions
iv) CLD development in order to:
v) Identify motors of innovation,
vi) Triangulate data

4. Event History Analysis of the Solar Water Heating Innovation System (SWHIS)

This section is chronologically structured into 4 phases of the evolution of the SWH industry in South Africa from 1978 to 2012. Within each of the phases events contributing to functions are listed together with external factors of that time. At the end of each account, a motor of innovation that played out in that phase is identified together with the structural barriers and drivers that enabled it.

1978-1983: Early Growth

Overview

The use of solar water heaters (SWHs) in South Africa dates back to the 1930s, however, it is only between 1978 and 1983 that their adoption in households increased. Early engagement with Solar Water Heating technology in South Africa was academic in nature, specifically, research and development of thermosyphon systems (Holm 2005). The two oil crises of the 1970s (1973 and 1978) are the main factors behind a revived interest in the technology. Also, in this period due to the isolation of the South Africa apartheid government, energy security is at the centre of the country’s energy policy (Winkler 2006). The Solar Water Heating project is viewed as a good strategy to address the above-mentioned issues. This government led project commences in 1978 (Prasad 2007). The Centre for Scientific and Industrial Research (CSIR)'s effective communication programme ensures early growth and development (Hardie 2011) by encouraging medium to high income household owners to install SWHs Prasad (2007). The homeowners achieve this either through home improvement loans or cash. As the demand for SWHs grows so does the market, during this time, six companies that manufacture, market and install SWHs become active, and in 1983 when the CSIR programme comes to an end, a total of 27 000 m^2 of solar collectors are installed (Prasad 2007).

Functional analysis and motor of innovation

The dominant function in this period is *Guidance of Search*, observed as the government begins SWH project. This is achieved through the CSIR's effective communication strategies, *Knowledge Diffusion*. CSIR's knowledge diffusion and awareness creation initiatives are successful and manages to convince homeowners to install SWHs. Six major companies become active in the industry and begin to manufacture, market and install SWHs, *Entrepreneurial Activities and Knowledge diffusion*. Resources are mobilised by homeowners to purchase the SWH systems, *Resource Mobilisation*. The *Guidance of Search* function is largely fulfilled by the government through the CSIR but also by the companies that market SWHs raising positive expectations about the technology. As a result, there is a strong fulfilment of the 'Resource mobilisation' resulting in even more raised expectations 'Guidance of search', 'Knowledge diffusion', and 'Entrepreneurial activities'. This dynamic is depicted in Figure 1, and referred to here as **'Project Motor'** as the it was primarily driven by the government. However, 3 functions remain unfulfilled, viz. 'Knowledge development', 'Market formation' and 'Advocacy coalition' as a result this dynamic is not resilient, largely driven by external factors. This is evident in the next episode, and will be detailed below.

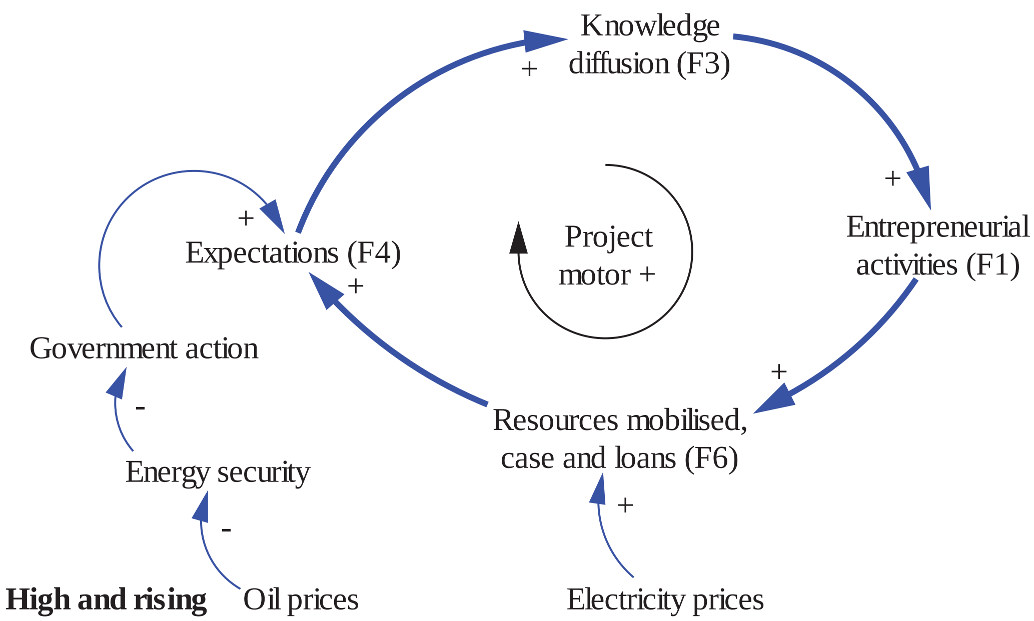

Figure 1: Project motor

Structural drivers and barriers

Responsible government departments and the Centre for Scientific and Industrial Research (CSIR) are the enactors in that their activities draw selectors into the SWH Innovation System (SWHIS). For instance, CSIR's good communication strategies can be viewed as a driver that is able to influence companies (selectors) to begin manufacturing SWHs and for customers (selectors) to purchase them. There are also two key external drivers in the period viz. the two oil crises of the 1970s and the energy security due to the isolation of the apartheid government. The government responds to these by coming up with a strategy that promotes SWHs via the CSIR, providing guidance of search, which is achieved through the diffusion of knowledge.

The disadvantage of this motor is that there are few actors, in particular enactors, additionally it hinges around Guidance of Search from government. The 'Knowledge diffusion' activity is therefore mainly achieved by one entity, the CSIR, and to some extent the six companies through marketing initiatives. Six companies are far too few to roll out SWHs to medium and high-income households in the country. There is also no long-term policy for a sustained roll-out of SWHs. The main institutional hurdle at the end of the phase is a lack of government's long-term vision for the industry, this is evident from the fact that when the CSIR funded projects end, the industry collapses.

Motor impact on the TIS structure

This motor has little impact in aligning the structure of SWHIS, however, it can be viewed as marking its beginnings. It will be another 25 years before the SWHIS becomes aligned. There are no institutional set-ups that are established during this period. It is not clear whether there are technology hurdles and improvements.

1984-1998: The collapse of the SWH industry

Overview

This period follows from a relatively successful SWH roll-out which collapsed when the CSIR education project was terminated. Holm (2005) notes that a decade subsequent to the oil crises South Africa goes into a relaxed mode and the interest in SWHs fades. In addition, all the sanctions that were imposed on the apartheid government were lifted after 1994, and national energy security is no longer an issue. Electricity prices are also low due to the abundant coal reserves from which South African electricity is generated. There are however pockets of activities within the SWHIS, for instance according to Holm (2005), W.N. Cawood developed a patented integral low-cost SWH for low-income housing in 1992, for a project commissioned by the National Energy Council.

Also, in 1995, the Department of Minerals and Energy (DME) commissions a workshop titled 'Solar Water Heating Action Workshop'. Its outcome is an action plan with identified priorities for government and other relevant stakeholders e.g. entrepreneurs, suppliers, financiers etc. (Holm 2005). The action workshop does not lead into any meaningful actions instead it leaves most of the actors even more disillusioned. Holm (2005) mentions that despite this, a list of action plans was produced that retained validity in the subsequent phases of the evolution of the innovation system. The number of glazed solar water heaters, the ones used for household water heating, dropped to less than half of the previous period, a mere 13 000m^2 (Prasad 2007; Holm 2005).

Functional analysis and motor of innovation

There is no dominant system function being fulfilled in this period. The collapse observed in this period is negative 'Guidance of search' due to the termination of the CSIR project. When the awareness project stops, 'Knowledge diffusion' is no longer being fulfilled. This means that fewer potential customers are enlightened enough to invest in SWH, a negative fulfilment of 'Resource mobilisation' which leads to companies, 'Entrepreneurial activities' collapsing. Due to the fact that all the system functions are negatively fulfilled and also reinforcing each other downwards, this motor is termed the '**Break-down motor'.** It is however important to note that there continues to be activity, there are some 'Knowledge development' activities, a low-cost SWH was patented, but this design was never taken up. Also there was a 'Knowledge diffusion' activity held, a solar Water Heating Workshop Action Workshop in 1995 that unfortunately left actors disillusioned. The dynamic in this episode is the same as the previous, '**Project moto**r', the same functions are being fulfilled, however reinforcing one another downwards due to the reversal of the external conditions, see Figure 2 below. The system's demise is a result of lack of resilience in the '**Project motor**', which collapsed when the external conditions changed.

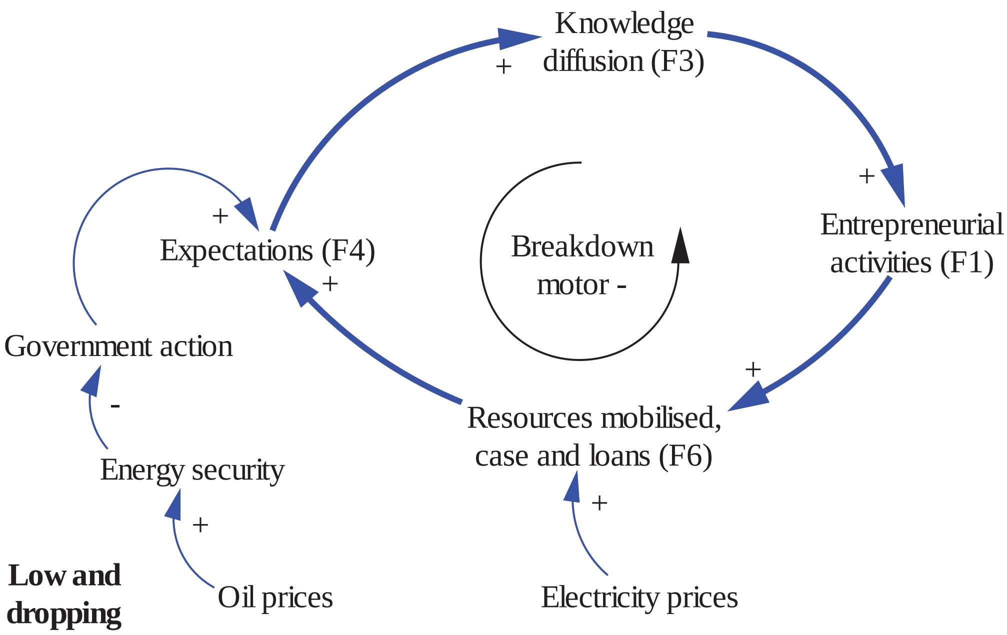

Figure 2: Break-down motor

Structural drivers and barriers

This motor is generally driven by external factors. The main ones are that the oil crises scare is over and that the South Africa electricity remains cheap due to abundant coal reserve. The stabilisation of oil market and cheap electricity prices made the renewable and energy efficient projects redundant. Another institutional driver comes into play when the sanctions are lifted at the dawn of the democratic government in 1994. There is some interest from the government that is meant to revive the SWH, and this can be seen when DME organises a conference to deliberate on the future of the industry.

The barriers in this episode are lack of concrete plans to introduce alternative and more efficient sources of energy into the energy mix. There are no pro-renewable energy policies in general and SWHs specifically. Instead, the energy policy aims to redress the injustices of the past (Winkler 2006) faced by the majority of the population who were previously denied basic services and SWH once again features as one of the ways of achieving this.

Motor impact on the TIS structure

The break-down motor distorts the structure of the SWHIS as some of the actors are no longer active. Despite the break-down, there is some indication that some enactors remain active, e.g. government, through the workshop that they organise, they continue to contribute towards the build-up SWHIS albeit at a snail pace. The interest that the workshop gathers indicates that some actors remain active in the innovation system, most likely due to '**Project Motor**' of the previous period. Ultimately, enactors of the previous period, the government and the CSIR become less active in drawing selectors into the innovation system.

1999-2007: The build-up phase

Overview

The dawn of the new democracy sees the country's energy policy change to focus more on equity and justice and in the late 1990s, into the 2000s it becomes more focused on meeting targets set after the 1994 election. Two of these priority areas are sustainable development and environmental protection. A White Paper on Energy which addresses this and other factors is released at the end of 1998 (Winkler 2006). Solar water heating is being seriously considered as one of the technologies that can address key policies, and there is in fact a renewed interest in SWHs from 1999.

The early days of this period sees the inception of several donor funded SWH projects. The focus of these projects, unlike in the two previous episodes, is on low-income households (Holm 2005). The first of such projects was Llwandle in Helderberg Cape Town where workers' hostels are transformed into family units (Prasad 2007). A total of 295 units are installed, it is noted that there is no maintenance plan in place for these system (Holm 2005). A similar project is also launched in Ivory Park, an informal settlement in the Gauteng province, where a R6 million grant is used for a pilot study to test the viability of SWHs in low income areas (Barry 2001; Monyai 2001). Other projects include eThekwini which saw 100 units subsidised by 50% installed in 2002, the Kuyasa project in Cape Town where 10 RDP houses were retrofitted with SWH in 2003, etc. (Holm 2005). In 2005, the Kuyasa project becomes the first CDM project to be awarded a gold standard, for its contribution in curbing greenhouse gas emissions, with a plan to grow it to 2300 households (Salgado, 2005). The Nelson Mandela Bay Metro in Port Elizabeth also optimistically plans to roll-out 100 000 SWHs (Hayward 2007).

Policies and/or strategies that promote renewable energy in general and solar water heaters specifically also come to the fore in this period. In 2002, the World Summit on Sustainable Development in Johannesburg raises awareness on sustainability issues in general. In 2003, a standard (SANS 62111:2003) for testing thermal performance of domestic SWHs is published (SABS Standards Division 2011). In the same year, the White Paper on Renewable Energy is published, it puts forward a target of 10 000 GWh of electricity to be generated from renewable energy technologies by 2013. This gives perspective and creates a renewed interest in the renewable energy sector. Towards the end of this period, the publication of the "Long-Term Mitigation Scenarios" maps out scenarios for economic growth vs. carbon emissions (Winkler 2007).

Most of the activity around SWHs is evident in local governments; especially in big municipalities. The activities include for instance drafting by-laws that promote SWH usage. For instance, The City of Cape Town municipality sets a target to install SWHs in 10% of household by 2010; in addition, they are drafting a by-law for use of SWHs in medium to high income households (Prasad 2007).

In addition, studies are conducted to investigate the market potential of SWHs. The Energy Development Corporation (EDC), a division of the Central Energy Fund commissions such a study with a grant from the UNDP, the study (Holm 2005). Some studies that are conducted investigate strategies to influence the demand of SWHs, for instance the City of Cape Town commissions such a study in 2005 (Essop 2005). CEF also undertakes a project called SWH 500: through this project 165 SWHs each in Johannesburg, Durban and Cape Town are installed in the first half of 2007 (Prasad 2007). Fifty of the 500 SWHs are meant to be monitored and measured for effectiveness (Star 2007). The project receives a lot of media coverage through Eskom and CEF articles published in local and national newspapers and revives interest in the technology (Enslin 2007; Star 2007). Government purchases its own test rig to test the outdoor performance of all the systems that will have the SABS accreditation (Star 2007).

Knowledge sharing platforms are more prevalent and attract strong interest: 3 workshops are held in the first half of 2007, one organised by ESKOM, the other by REEEP/CEF and the last a workshop as part of the International Domestic Energy Use Conference to deliberate on how growth in the industry can be influenced.

The industry gets further boost when a solar heating division under the Sustainable Energy Society of Southern Africa (SESSA) is formed, an interest group begins to participate and advocate on behalf of their members to get better market conditions (Star 2007). The body is made up of suppliers, academics and interested members of the public. The division is meant to support Eskom in its future planning, assist the SABS with updating SWHs standards and support pilot studies that the government is conducting, for instance the SWH 500 Project (Star 2007). In addition, it runs a programme known as SESSA50 in which they install subsidized SWH units with the aim of collecting data to help carry a detailed analysis of the technology which informed the SWH SABS standards (Holm 2005; Prasad 2007). Another initiative formed in the in this period is called Ubushushu Bendalo, 'Heat from Nature' formed between civil society and the City of Cape Town with plans to effectively implement RE and energy efficiency with a specific focus on SWHs.

Shortly after the rolling blackout experience in 2006 in Cape Town (Marrs 2006)**,** Eskom announces plans to invest R2-billion in the roll-out of SWHs, an announcement that made headlines in major newspapers (Davie 2007; Enslin-Payne 2007; Financial Mail 2007).

Functional analysis and motor of innovation

The dominant dynamic in this period is that of knowledge building. The momentum is provided by grants from international donor agencies 'Resource mobilisation' that fund some government agencies to conduct market surveys and pilot project for 'Knowledge development'. 'Guidance of search' is stronger than in the previous periods. This does not come from one facet of government, e.g. Department of Energy, municipalities are also active drafting by-laws that will provide a conducive environment for the roll-out of SWHs, a good example is the City of Cape Town which has been active in setting targets and drafting by laws. Other municipalities such as Nelson Mandela Bay and eThekwini are also actively embarking on SWHs projects. Further but indirect 'Guidance of Search' comes from national government, for instance the publishing on the White Paper on renewable energy.

The biggest 'Guidance of search' comes in 2007 comes when Eskom announces plans to invest R2 billion for the SWHs roll-out. The publishing of the first SWH in 2003 and the facility to test for thermal efficiency of SWHs provides further useful information on the performance of SWH systems in the market. This period also sees the formation of industrial bodies that also serve the advocacy role 'Advocacy Coalition', the SWH division of SESSA as a platform for voicing industrial concerns. Summits and knowledge sharing platforms also feature 'Knowledge diffusion'. There are hardly new companies being formed in the early 2000s, there are only 4 recognised companies SWHIS (Holm 2005). This number however increases 2005, new companies join the industry and become members of SESSA, this is driven by CEF initiatives from 2005 and about 87 companies operate at the end of 2007 (Hardie 2011). Figure 3 below captures how these events reinforce each other in a causal loop diagram. Six of the seven functions, all except 'Market formation' are being fulfilled in this season, a real momentum is observed within the SWHIS and carries through the last episode.

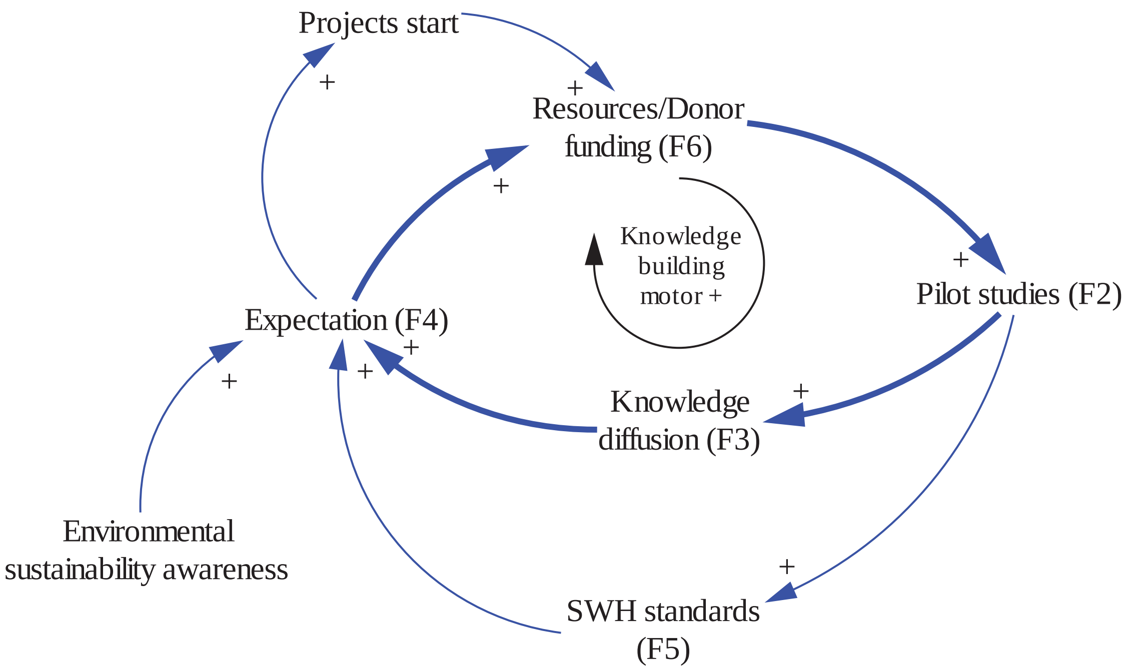

Figure 3: Knowledge building motor

Structural drivers and barriers

Sustainability and climate change issues become national and international priorities and largely influence how the SWHIS shapes in this period. On the other hand, in South Africa, there are high levels of unemployment and the SWH industry can help address this national challenge. Municipalities are becoming increasingly interested in the technology for energy efficiency and greenhouse gas emissions (GHGs) reduction targets. Eskom's proposed project changes the landscape and can be seen here as a big driver on how the SWHIS shapes in the next episode.

The main barrier in this episode as in the previous two, is the lack of concrete policy by national government with regards to solar water heating industry. Most of the efforts are driven by Eskom and CEF (with funding from UNDP) initially in feasibility studies and subsequently in pilot projects. The certification of solar water heaters, crucial for the industry to have credibility is at its infancy, and the registration process that the SWH division of SESSA is facilitating is still slow. There are however still few Solar Water Heaters companies to realise the estimated potential. Finally, there are no drivers in the form of regulations to fulfil the 'Market formation' function

Motor impact on the TIS structure

The most significant impact that the 'Knowledge Building' motor has on the TIS structure is the build-up and strengthening of knowledge within the SWHIS. For instance, there is clarity on how the performance of the SWH systems are assessed, through the establishment of the performance testing rig at the SABS facilit. Moreover, SABS SWH thermal performance standards are introduced for the first time in 2003. Also, the market surveys give a positive outlook of the sector which serves to draw into SWHIS selectors.

In terms of the impact on the actors specifically, selectors are drawn into the SWHIS (e.g. when new companies are formed or old companies diversify into SWH technology) and themselves become enactors. A substantial number of enactors subsequently organise themselves. This results in a much bigger Solar Water Heating division, previously known as SolaSure, which becomes more active in lobbying for better industrial conditions. The dynamic has to some extent been able to draw a lot more actors e.g. municipalities, new companies into SWHIS than previous episodes. The structure is therefore more developed and poised for further growth and strengthening.

2008-2012: A new dawn for the SWH industry?

Overview

Sustainable development and climate change remain high on the agenda internationally but also nationally (Madzwamuse 2010). Nationally, there is pressure as Hardie (2011) notes, to reach a 2013 renewable energy target alluded to earlier, set in the White Paper on Renewable Energy. This episode begins with electricity supply crisis in January 2008, which results in rolling blackouts nationwide (Odhiambo 2009; le Roux 2008). SWHs are viewed as one of the options that can address the issues mentioned above.

Eskom begins to intensify its efforts around the SWH programme as a Demand Side Management (DSM) strategy. Although this is announced towards the end of the previous episode 2007, more inroads are made early in 2008 (Kritzinger 2011). Meanwhile, the SWH market continues to grow, for instance, a survey conducted in 2010 found that the number of installations increased by about 79% between 2007-2008, from 87 installation in 2007 to 147 installations per firm in 2008 (Hardie 2011), driven largely by rolling blackouts. Early in this episode, Eskom announces its SWH subsidy programme with the plans to subsidize 925 000 SWHs in a period of 5 years (average subsidy is R4200 per installation) at this time Eskom had 26 accredited SWH suppliers but they have since increased to more than 400 (Hardie 2011; Bega 2008). A 2008 survey of the industry establishes that the number of unglazed SWH installations have reached an all-time high, 34 000m^2 compared to 27 000m^2 in 1983 and this largely attributed to load-shedding in the few beginning months of 2008 (Eskom 2011).

Renewable Energy Market Transformation Unit which is housed at the DBSA under the auspices of DoE host a workshop, one of the main calls at this workshop was for the government to establish financing mechanism to facilitate mass roll out incentives. This workshops informs a nationwide workshop held in March 2009, ‘National SWH Workshop organised by the Renewable Energy Market Transformation (REMT) unit within the DME, 155 participants, mostly active industry actors take part with the aim finding out and possibly influencing government to invest in the industry to encourage its growth (REMT Unit 2009).

Following the National Workshop SWH, the Department of Energy (DoE) organises a National Solar Water Heating Conference. It is at this conference that the Minster of DoE announces that government’s SWH programme, which aims to roll out 1 million SWHs by 2014 via incentivised programmes. This was followed by an increase in the number of new companies that enter the industry. Media continues to write positively about the SWH industry (Yeld 2008; Thakali 2008; Ingi Salgado 2010) encouraging traditional water geyser companies e.g. Kwitol to diversify into the solar water market. The Minister’s announcement, spurred several activities including the setting up of maintenance and training facility in Soweto (Hardie, 2011). Even some unlikely selectors contemplate on whether to enter the industry, South African Insurance Association announces that the short term industry is investigating on whether to create a value proposition to replace the electric geysers with more energy efficient SWH. A short term insurance company (Santam) actually invests its resources in a out pilot projects, the knowledge gained has been shared with other interested actors, and ultimately inspiring other short term insurance to enter the market (Kritzinger 2011).

A few months after the Minister’s announcement of 1 million rollout of SWH, the South African President launches the National Solar Water Heating Programme in Tshwane where 270 systems were installed with the financing from CEF, this catalyses entrepreneurial activity as more companies enter the industry (Salgado, 2010).

However in 2011, local SWH manufacturers lay a complaint with Eskom, their woe is that they are taking strain due to cheap Chinese imported SWH, which results in a few companies being forced to close down (Gosling 2011). The local manufacturers lobby government and Eskom to offer better incentives for local manufactures. The Congress of South African Trade Unions (COSATU) holds a protest in support of local SWH manufactures, lobbying for better incentives for locally manufactured units compared to imported units. Their lobbying is successful; the Minister of DoE announces in her annual speech that as of 2012, the solar water heater programme will work on a different model. In essence, only those suppliers who commit to localise their product will be able to participate in the government funded subsidy programme, this addresses concerns of local manufacturers. In the meantime, Treasury allocates R4.7 billion to promote SWH programme, the Minister of Finance announced in his annual budget speech (Department of Energy 2012).

Functional analysis and motor of innovation

The dominant functions in this episode are ‘Guidance of search’ and ‘Market formation’, coming from government’s plans to roll out solar water heaters. Policy direction has largely been missing in the previous episodes and features strongly in this one. The fulfilment of ‘Guidance of search’ and ‘Resource mobilisation’ lead to increased ‘Entrepreneurial activities’, there are more SWH companies in this period than in any stage of SWHIS development. Moreover, subsidies by Eskom provide further guidance while fulfilling Resource mobilisation function.

Municipalities also continue to pursue their own SWH programmes, e.g. The City of Cape Town, Ekurhuleni, Nelson Mandela Bay, eThekwini, further providing guidance to the sector. Advocacy also features strongly in this episode, for instance, industrial bodies are able to influence government actions to protect the local SWH manufacturers from cheap Chinese imports. ‘Knowledge development’ is not fulfilled as strongly, as the technical aspect of the SWHs is no longer an issue, it is however being fulfilled by several pilot studies and market surveys at the beginning of this episode. More ‘Knowledge diffusion’ activities are noted however, the main ones that contributed to a change in the Solar Water Heater landscape is the workshop organised by REMT on behalf of the Department of Energy (DoE) which was followed by a National Solar Water Heater Conference. It was at the National Solar Heater conference where an announcement of 1 million SWH roll-out programme by government was made, which the president later launched in early 2010.

The dominant dynamic here is that of an emerging ‘**Market Motor**’, all the functions are being fulfilled and are reinforcing one another into virtuous cycles. It is important to note that this motor is still at its infancy, as ‘*Advocacy Coalition’* still features strongly and could thus affect the trajectory of the SWHIS. In previous studies, (Suurs & Hekkert, 2009; Suurs et al., 2010), this motor is characterised by low or no fulfilment of advocacy as the needs of the government and the market are more aligned. There is a strong case to label this motor a **‘Market Motor’,** see Figure 4 below**,** because of strong growth relative to subsequent periods with a strong growth potential as a result of immense support from national government.

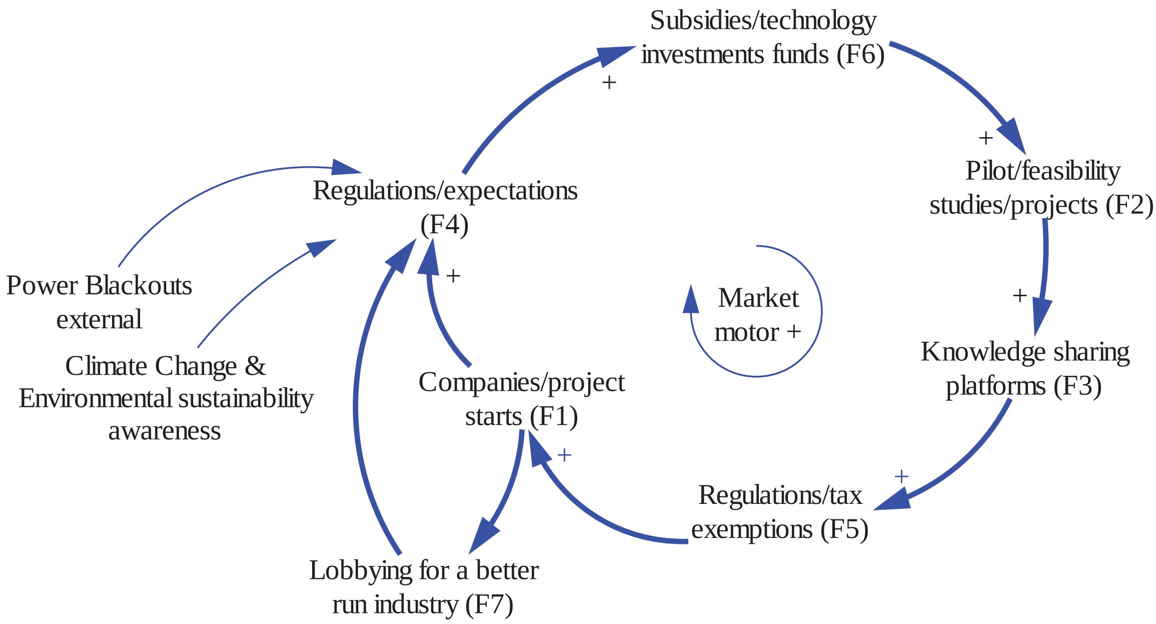

Figure 4: Market motor

Structural drivers and barriers

External drivers that were prevalent in the previous two episodes, viz. climate change and sustainability continue to feature in this episode. Locally, the main driver observed at the beginning of this episode, are the rolling power blackouts. This could have contributed to swift strides that government made in support of the SWH industry. This leads to the speedy announcement of 1 million SWH roll out by 2014 which is accompanied by resource mobilisation, mooted in 2009 and officially announced in 2010. Other drivers facilitated by actors include the lobbying government to fulfil its mandate on creating ‘green’ jobs as a strategy to curb unemployment. This is achieved by lobbying for better local industry conditions by Cosatu and SWH division of SESSA.

The main institutional driver has been from the government’s side through the announcement of the National Solar Water Heater Programme. The media’s positive reporting of some of the programme and pilot projects has increased the technology’s publicity.

The barrier in this episode continues to be relatively low uptake of the technology relative to the target that the government has set for itself. More fulfilment of knowledge diffusion is needed to communicate the benefits of adopting the technology to potential customers. Therefore enactors should set strategies around knowledge diffusion.

Motor impact on the TIS structure

The picture in this dynamic is that of a mature SWHIS. The industry appears to be taking off. This can be observed by the drastic increase in SWH companies, from less than 10 in the mid-2000s to well over 400 in 2012. Therefore a number of enactors increase drastically, thus the enactors (companies, municipalities, government departments, Eskom, CEF) have been able to draw in selectors, mostly new firms which become part of the industry association (SESSA). As a result, SESSA has more mass to lobby for change.

Government strategy has played a key role in how the innovation system has shaped in this episode. This seems to have been able to communicate the relevance of the technology as a solution to some of the local social issues e.g. unemployment. Government backed up its strategy and policy; this is evident when the Minister of Finance sets R4.7billion aside for subsidies. The government's introduction of tax rebates to stimulate the development of the industry has also been important.

5. Discussion

The main objective of this paper was to test the utility of the Technological Innovation System (TIS) approach framework in South Africa. This was achieved by tracking events in the development of the Solar Water Heater (SWH) industry in South Africa from 1978 to 2012 using an event-history analysis approach (Van de Ven et al, 2000). Firstly, the utility of the TIS approach was tested by assessing whether events that unfolded in the SWH industry during the period studied are attributable to all the 7 system functions proposed by Hekkert et al (2007). It was discovered that all events documented in this study fulfil all the 7 system functions. However, unlike in developed countries, where advocacy coalition and market formation played a crucial role in influencing the development of a TIS (Negro et al, 2007; Hekkert et al, 2007; Suurs et al, 2009, Suurs and Hekkert, 2009), these were not as prevalent in the South African SWH case study.

In the first successful period of the industry (1978-1983), the main external drivers were the 2 oil crises of the 1970s and the resultant high energy costs, when that period of uncertainty passed, the industry collapsed. The revival of the SWH industry from the year 1999 onwards was due to a number of factors, amongst them an increased awareness of external factors viz. commitment towards GHGs mitigation; a need to provide services to the population; and the biggest driver that came to the fore from 2008 onwards was the increase in electricity prices following the power crises that resulted in blackouts nationwide. As a result the dominant system function that was prevalent in all other episodes except the 2nd episode is 'Guidance of search'. It particularly features strongly in the last episode as for the first time there was a national strategy for solar water heating technology specifically.

Secondly, the purpose of the study was to gain insights into the dynamics that shaped the development of the SWH industry by identifying the underlying 'motors of innovation' as proposed by Suurs and

Hekkert (2009) and Bergek et al (2008). Four different 'motors of innovation' were identified during the period studied viz. '**Project Motor**' in the 1st, the '**Breakdown Motor**' during the 2nd episode, the '**Knowledge Building Motor**' in the 3rd episode and '**Market Motor**'. In the 1st episode, 'Guidance of Search' from the government with regards to disseminating the technology resulted in the fulfilment of the 'Knowledge Diffusion' function by the CSIR which led the fulfilment of 'Entrepreneurial Activities' and 'Resource Mobilisation. Through the CSIR programme the 'Knowledge Diffusion' function continued to be fulfilled resulting in the reinforcing of the previous 3 functions.

In previous studies, a '**Market Motor**' is usually achieved when all 7 system functions reinforce each. This is observed in the final episode of the period studied where all functions are fulfilled, however the 'Knowledge development' to a far lesser extent as technical problems no longer issues. Most knowledge development activities were on how to speed the dissemination.

The revival of the industry in the 3rd and 4th episodes was a result of 'Guidance of search' and 'Knowledge diffusion' from CEF, Eskom and municipalities and in the later part of the episode by national government. The feature of the episode is the stronger fulfilment of all the 7 system functions, including 'Advocacy coalition' (albeit not as strongly as in European studies as mentioned above) and 'Knowledge development' in the form of pilot projects which has not been prevalent in the previous 2 episodes. SESSA is playing an instrumental role, especially through the SESSA50 programme. Eskom is also realising the role that SWHs can play as part of Demand Side Management and becomes an enactor and through the rebate programme attracts more entrepreneurs into the industry which was further strengthened by the introduction of National Solar Water Heater Programme that aims to install 1 million SWHs by 2014.

The dynamics referred to here as motors of innovations are influenced by structural barriers and drivers at the same time influence the configuration of the structure. Various impacts were noted to have influence the dynamics in each of the episodes, and instrumental in determining which system functions dominate the episode. For instance in the 1st episode in which energy security and oil crises were external drivers, the government introduced a project that led into an emergence of the of the Solar Water Heating Innovation Systems (SWHIS). However the situation changed when the project, which by design didn't have long-term goals collapsed, and so do did the SWHIS. The positive outcome of that episode is that some enactors (SWH companies) remained within SWHIS and were instrumental in the revival in the later years.

In the last episodes, external drivers provided direction for the SWHIS with the absence of concrete national strategy; this is established in the final one. This is realised in the final episode, which leads to a mature structure of the SWHIS with a lot of actors, enactors and selectors, strong networks, for example SESSA, and good institutions, rules of the game, which are clearer and understood by majority of the actors within SWHIS. Therefore the market dynamic has been instrumental to a mature innovation system.

6. Conclusion

The main objective of this paper was to test the utility of the Technological Innovation System (TIS) approach, esp. using the system functions framework, to understand the build-up of the South African Solar Water Heater Industry. The study has helped identify the functional constellations that were prevalent during each of the 4 periods studied, described as motors of innovation. It has demonstrated which of the functions ought to be fulfilled, in order that the TIS structure is aligned. The applicability of causal loop diagrams in depicting the dynamics of the system was also demonstrated and found useful in depicting the narrative.

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An age structured demographic model of technology

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Abstract

At the heart of technology transitions lie complex processes of technology choices. Understanding and planning sustainability transitions requires modelling work, which necessitates a theory of technology substitution. A theoretical model of technological change and turnover is presented, intended as a methodological paradigm shift from widely used conventional modelling approaches such as cost optimisation. It follows the tradition of evolutionary economics and evolutionary game theory, using ecological population growth dynamics to represent the evolution of technology populations in the marketplace, with substitutions taking place at the level of the decision-maker. Extended to use principles of human demography or the age structured evolution of species in interacting ecosystems, this theory is built from first principles, and through an appropriate approximation, reduces to a form identical to empirical models of technology diffusion common in the technology transitions literature. Using an age structure, it provides the appropriate groundwork and theoretical framework to understand interacting technologies, their birth, ageing and mutual substitution. This analysis provides insight in explaining the nature and origin of observed timescales of technology transitions, in terms of technology life expectancies, the dynamic process of production capacity expansion or collapse and its timescales, in what is termed a ‘demographic phase’. While this model contributes to the general understanding of technological change, the information in this work is intended to be used practically for the parameterisation of technology diffusion in large scale models of technology systems when measured data is unknown or uncertain, as is the case for new technologies, notably for modelling future energy systems and greenhouse gas emissions.

1. Introduction

1.1. Creative Destruction

Systems of technologies and their interactions are notoriously complex to model and understand, but such an understanding is crucial for anticipating and informing the planning of sustainability transitions. Socio-technical systems generate crucial *societal functions* (Geels, 2005, 2002), and these services and their demand are in a continuous evolution. Meanwhile, the evolution of technology generates new opportunities to society that enable the creation of activities that did not exist previously, producing a complex interaction between technology, society and the economy, even generating economic growth through Schumpeter's widely discussed but not well understood process of `creative destruction' (Schumpeter, 1934, see also for instance Nelson and Winter, 1982). Technological change occurs through a gradual process of technology substitutions which stems from a continuous stream of decision-making performed by a myriad of actors involved in the operation of technology or the consumption of the services it generates (Grübler, 1998; Grubler et al., 1999). This spans from, for example, the power sector, vehicles for transport, communications and information technologies, heating, cooling and lighting equipment and so on, in other words, in sectors performing societal functions, of which the underlying generation technologies, and their associated socio-technical standards, are not unique. Change in such sectors occurs through the choices of consumers or investors facing various alternatives and incomplete information, and these decisions are based, in a context of *bounded rationality*, on diverse sets of considerations and constraints (concepts well explored by Nelson and Winter, 1982).

The process of technological change is not currently well described by any generally accepted theory (observing the contrast between approaches for instance of Geels, 2002; Grübler, 1998; Safarzynska and van den Bergh, 2010). However, a significant and well known body of empirical literature exists that consistently describes the process of technology substitutions through gradual *S*-shaped curves (e.g. Mansfield, 1961; the best reviews probably remain the work of Grübler, 1998; Grubler et al., 1999). These trends strongly suggest a parallel with ecological theories of population dynamics (e.g. Metcalfe, 2004), the best known and most appropriate consisting in using the Lotka-Volterra system of population growth equations for the competition of species (for an explanation and history see Andersen, 1994), or the replicator dynamics equation of evolutionary game theory (Hofbauer and Sigmund, 1998). While this idea has strong support in the fields of evolutionary and industrial economics, it also makes intuitive sense to perceive competing technologies (or even socio-technical systems) in the marketplace similarly to competing species in ecosystems (or even competing sub-ecosystems and food chains). The parallel has been brought much further with the development of evolutionary game theory (Hodgson and Huang, 2012; see also Hofbauer and Sigmund, 1998), the key authors of which, such as Maynard Smith and Price, were acutely aware of the strong analogy that could be drawn between the mathematics of the evolution of genotype frequencies and their selection in a population in biology, and the process of innovation and technology diffusion in economics. In addition to providing a definition to the concept of bounded rationality, this strand of literature demonstrates that the parallel, although described with yet insufficient precision, is more than just intuitive (Metcalfe, 2008, 2004).

The description of technological change or technology evolution following parallels with ecology currently remains in the conceptual and theoretical domain (for a review, see Safarzynska and van den Bergh, 2010) or in stylised form (e.g. 'history-friendly models' of Malerba et al., 1999; or Safarzynska and van den Bergh, 2012) and not quite adapted to actual quantitative applications such as forecasting the generation of particular goods or services, technology mixes or the economic or environmental impacts that these may have. Geels, 2002, with his multi-level perspective, rightly describes the diffusion of socio-technical systems as much more complex than simple substitution events represented by a set of coupled differential equations, involving niches, early uncoordinated innovations and transformations in the social context, seemingly precluding any modelling attempts. Despite this, it is remarkable that diffusion processes have been observed in a myriad of contexts to follow very closely logistic curves or the more general Lotka-Volterra system of equations (Farrell, 1993; Fisher and Pry, 1971; Lakka et al., 2013; Mansfield, 1961; Marchetti and Nakicenovic, 1978; Sharif and Kabir, 1976; Wilson, 2012, 2009, and many more), and that such a simple patterns *emerge* out of the underlying complexity.

The problem can be simplified by restricting the analysis to the diffusion component, excluding the early erratic innovation process, assuming that new but established technologies permeate the landscape in dormant niches that could wake up and diffuse massively given the right environment, for instance with targeted policy. From then onwards the diffusion process, gaining momentum, becomes firmer and simpler to project quantitatively. Although the quantitative prediction of technology diffusion is inherently highly uncertain, in parts due to the actual evolutionary nature of technology evolution, it is nevertheless a highly worthwhile venture to undertake, particularly for the a climate change mitigation context, where it finds several important applications in energy intensive sectors (e.g. power generation, transport, industry).

While concepts of technology diffusion provide appropriate insight on the key dynamics involved, they have not been used significantly in the modelling literature beyond the empirical description of *past* data using the observed *pattern*, the logistic curve (Fisher and Pry, 1971; Marchetti and Nakicenovic, 1978; Nakicenovic, 1986; Sharif and Kabir, 1976; Wilson, 2012, 2009 and many more). With the exception of the author's model of the global power sector, *FTT:Power* (Mercure, 2012a), the process of technology diffusion has yet to be even considered in large scale cross-sectoral models such as those for energy systems modelling, where they could find significant practical applications, for instance in projecting energy use and greenhouse gas emissions. This is partly due to the fact that, while this type of theory suggests a system for forecasting technology or market evolution, such projections would rely on measured scaling parameters, which can be reliably measured only precisely in cases of older technologies where transitions have already occurred. Effectively, by the non-linear nature of the problem itself, obtaining such scaling parameters for new technologies for which forecasting would be critically important cannot be reliably done based on the small amounts of available data.[1] This suggests that high gains could be generated if new insight could be found on how to obtain these parameters through other means than the empirical fitting of diffusion data, requiring to establish a quantitative theory to understand their nature. These parameters are *timescales*, and this suggests that their meaning is associated to the use, the advent and the demise of technology in time.

Ground work for building a theory of technology substitution and diffusion has been done in previous work. The first part consists with the definition of *FTT:Power*, a global model of technology diffusion, electricity generation and greenhouse gas emissions based on technology population dynamics and bounded rationality (Mercure, 2012a). The second part is an expansion of the theory of technology dynamics, separated from the associated problem of decision-making under bounded rationality for clarity, describing the structure of population dynamics equations in terms of growth and decommission rates (Mercure, 2012b). While these timescales are intuitively understood in terms of technology properties, they remain however exogenous to the model and their origin requires further explanation. This paper thus presents the theoretical elements necessary to construct a theory of technological change that uses scaling parameters that can be derived from the properties of the technologies and the industrial structures involved.

[1] E.g. fitting logistic curves requires data that spans at least beyond the inflexion point.

1.2. The Lotka-Volterra equation for empirical technology transitions

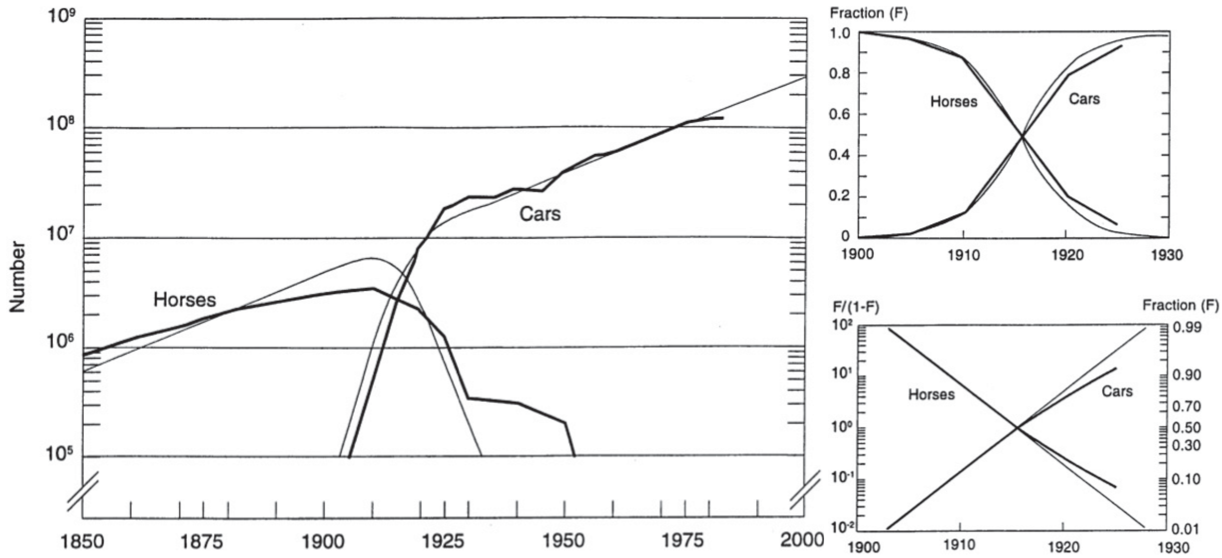

Figure 1: Transition from horses to cars in the 1920s (Nakicenovic, 1986). (*Left*) Raw data on a semi-log axis. (*Top right*) The data, when expressed as fractions of the total *F*, follows very closely logistic curves. (*Bottom right*) This demonstrated by a transformation of the data of the form *F/(1-F)* on a semi-log axis, which produces nearly linear trends.

The parallel between technology and ecology can be summarised as follows. Figure 1 presents the iconic data from the work of (Nakicenovic, 1986) for the transition between horses and cars that occurred in the 1920s. In this data, a transition is observed superimposed on an exponential growth of the number of vehicles. Through closer inspection, one observes that by dividing the numbers of horses and cars by the total number of transport units, functions reminiscent of logistic curves are observed which cross each other in around 1915. This is demonstrated to be a very accurate assessment by displaying the fractional data (using *S* here for market *Shares*) as *S/(1-S)* on semilog axes, generating linear trends:

$$\log\left(\frac{S_1}{1-S_1}\right) = \alpha_{12}(t-t_0), \quad \log\left(\frac{S_2}{1-S_2}\right) = \alpha_{21}(t-t_0), \quad \alpha_{12} = -\alpha_{21} \qquad (1)$$

which corresponds to logistic forms,

$$S_1 = \frac{1}{1+\exp\big(\alpha_{12}(t-t_0)\big)}, S_2 = 1 - S_2 = \frac{1}{1+\exp\big(\alpha_{21}(t-t_0)\big)} \qquad (2)$$

Taking a differential form for these expressions, one obtains

$$\frac{dS_1}{dt} = \alpha_{12}S_1(1-S_1) = \alpha_{12}S_1S_2, \quad \frac{dS_2}{dt} = \alpha_{21}S_2S_1 \qquad (3)$$

This example depicts the interaction occurring within a pair of technologies. Geels, 2005 criticises the analysis of Nakicenovic, 1986 by invoking the presence of two other important transport technologies, which have interacted with and influenced the development of petrol vehicles but have not pervaded the market, namely electric trams and bicycles. Effectively, in most cases of technology competition, it is nearly impossible to exclude the existence of a third interacting component, and a fourth and so on,[2]

$$\frac{dS_1}{dt} = \alpha_{12} S_1 S_2 + \alpha_{13} S_1 S_3 + \alpha_{14} S_1 S_4 + \cdots \quad \Rightarrow \frac{dS_i}{dt} = \sum_j \alpha_{ij} S_i S_j \qquad (4)$$

generalising the theory to an arbitrary number of technologies interacting in the marketplace, with interaction time constants held in the antisymmetric matrix α_{ij}. In this form, it corresponds to the expression for the replicator dynamics well discussed in evolutionary game theory (Hofbauer and Sigmund, 1998) and evolutionary economics (Safarzynska and van den Bergh, 2012). It is also mathematically equivalent to the Lotka-Volterra system of differential equations for the numbers of individuals in a set of competing species when expressed in absolute numbers,

$$\frac{dN_i}{dt} = r_i \left[N_i - \sum_j \frac{\alpha_{ij} N_i N_j}{K} \right] \qquad (5)$$

where the first term $r_i N_i$ is the *birth* of individuals with *birth rates* r_i, generating an exponential growth component, but the second term, negative, expresses both the interference of a specie with itself, when resources become scarce and individuals begin to compete, or the interference across species competing for the same resources. The new parameter K is the *carrying capacity* of the ecosystem, the number of individuals that the system can accommodate. In the technology context, the carrying capacity corresponds to the total number of units of technology supplying the demand for a service, or societal function, following a *demand led* economic assumption. Birth rates however have not yet been very clearly defined.

1.3. A demographic model of technological change

This paper presents a model of technological change that follows from the premise given above, using a replicator dynamics equation, with an additional attempt at providing meaning to its parameters (α_{ij}, r_i, K) in terms of information that can be obtained when dealing with technologies for which transitions have not yet occurred, making the parameters difficult to extract empirically from data. As I shall show, the replicator dynamics approach provides a clear definition of decision-making and bounded rationality, and divides the decision-making problem to the one of technology population dynamics, which can be treated separately. Thus the decision-making problem, while treated in the simplest possible form of bounded rationality ('profit-seeking as opposed to profit maximising', (R. R. Nelson and S. G. Winter, 1982b) for clarity in my definition of *FTT:Power* (Mercure, 2012a), will be explored into more detail elsewhere. The crucial information required in modelling technology

[2] The perverse effect of using quantities relative to the total is that this method can easily lead to overlooking other competing technologies that only hold small market shares.

populations being the *timescales* of transitions, it must be strongly grounded in time-related concepts such as rates of capital investments and technology life expectancies, or in other words, technology birth and death processes. Since technologies *do possess* life expectancies and birth rates, it becomes unavoidable to consider making use of the massive but well trodden apparatus of age structured human demography. Several independent strands of demography exist, using either a continuous or a discrete form, all shown to be equivalent by Keyfitz, 1977, of which I shall choose the continuous form in order to maintain a close relationship with the empirical work described above. Human demography in the continuous version corresponds in essence to an age structured form of single specie population dynamics. It provides an in-depth view of the process of population evolution through age specific stochastic birth and death events, using probabilities of giving birth and of dying for age tranches covering a whole lifetime, in other words, age specific birth and death rates. This provides demographers with much finer accuracy for population projections than the use of crude average birth and death rates. A system of competing species can also be described using an age structure, providing a similar accuracy improvement in the projection of interacting populations, if it is integrated to a competition model. I thus create here such a construction for technology dynamics, which, as I will show, demonstrate the origin of the shape of the technological change process due to its key property of *self-correlation* in time.

In contrast to demography, however, the birth of technology does not occur through pregnancy. Technology birth takes place inside of the industrial structure through the investment of financiers in production capital and labour, using for this the profits generated by the sales of these same technologies. Sales are the process by which population expansions can take place: if sales increase, the production capital and labour can be expanded, but if sales decrease, the production capital and labour must eventually shrink. The aim of this paper is thus to describe the process of birth, death and turnover of technology from first principles, based on assumed knowledge of the properties of technologies and their associated industries, but no knowledge of the structure of the anticipated technology transitions. This paper progresses as follows: I first describe independently the process of technology death, and then birth, and show how these generate a self correlation of population numbers in time. I then construct an age structured model of interacting technology populations. In a particular approximation under specific constraints, this model is shown to reduce to a Lotka-Volterra competition system. This process uncovers the origin of the parameters of the Lotka-Volterra equation, grounded in demographic theory. While death rates are nearly obvious, the structure of technology birth rates is more subtle, and this calculation generates insight on their meaning in terms of industrial dynamics. This is explored at this point. I then close the analysis with a discussion in terms of the multi-level perspective, defining a *demographic phase* of technological change, which takes place after innovation generates coherent seeds of technology diffusion that reside in technology niches. I then present a description of the practical use of this theory in applications such as energy systems modelling, but also of the general understanding of technology transitions.

2. The birth and death of technology

2.1. The destruction process

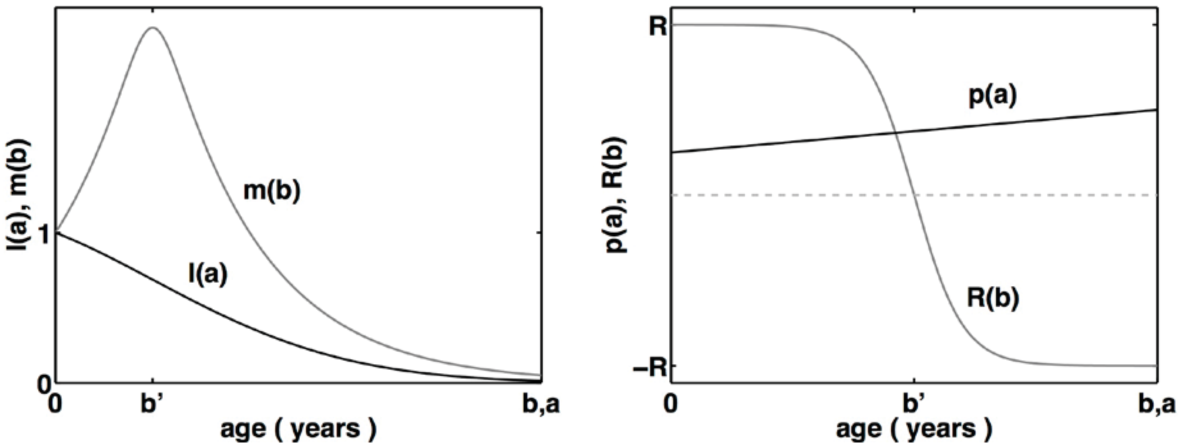

Figure 2: Depiction of the survival function $\ell_i(a)$ and the birth function m(b) (*Left*), which respectively stem from the instantaneous force of death $p_i(a)$ and the reinvestment schedule $R_i(b)$ (*Right*). The reinvestment schedule becomes negative when the maintenance of old production capacity exceeds its income and it is gradually taken out of operation.

The death of technology units can occur in different ways with different probabilities. For example, in the transport sector, vehicles can be taken out of the system through fatal accidents, or by random failures during their lifetime, or perhaps by economic decisions due to the cost of maintenance increasing towards old age.[3] These processes have different probabilities of occurring as functions of vehicle age. For a technology of type or brand *i*, taking the probability of destruction at age *a* as $p_i(a)\Delta\text{a}$, and the number $n_i(a,t')\Delta\text{t}'$ of technology units produced between year t' and $\Delta\text{t}'$ (or age interval Δa),[4] the change in this age distribution $\Delta n_i(a,t')$ of technology units during an ageing interval Δa due to destructions is

$$\Delta n_i(a,t')\Delta t' = -p_i(a) n_i(a,t')\Delta t'\Delta a \tag{6}$$

In the continuous limit ($\Delta a \to 0$), this solves to

$$n_i(a,t')\Delta t' = n_i(0,t')\ell_i(\text{a})\Delta\text{t}', \quad \ell_i(\text{a}) = \exp\left(-\int_0^a p_i(a')da'\right). \tag{7}$$

$\ell_i(a)$ is the common demographic *survival function*, while $p_i(a)$ is the instantaneous *force of death* (see for instance Keyfitz, 1977). This is depicted in Figure 2. These are normally derived in demography from life tables where individuals are traced during their lifetime from birth until death.

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[3] The existence of *sunk costs* imply the existence of a non-zero life expectancy.
[4] E.g. the number of 2003 Citroen C3 currently 10 years old.

The various processes of technology death can be associated to components in $\ell_i(a)$. Accidents normally have a constant force of death, and therefore give $\ell_i(a)$ a simple exponential form. Meanwhile, scrapping due to failures tend to occur later during technology life, with increasing values of $p_i(a)$. Thus $\ell_i(a)$ can be written as

$$p(a) = \frac{1}{\tau_1} + \frac{a}{\tau_2^2} + \frac{a^2}{\tau_3^3} + \cdots, \quad \ell(a) = \exp\left(-\frac{a}{\tau_1} - \frac{a^2}{2\tau_2^2} - \frac{a^3}{3\tau_3^3} - \cdots\right) \tag{8}$$

each term corresponding to different processes with respective timescales τ_n. If accidents dominate the destruction process, then $\ell_i(a)$ should take predominantly an exponential form, while if the probability of failures dominates and increases approximately linearly with age, $\ell_i(a)$ takes the form of a gaussian, and so on. The survival of transport vehicles in the USA was shown to follow approximately a mixture of τ_1 and τ_2 processes (and references therein ORNL, 2012). While $\ell_i(a)$ expresses the probability of a technology unit to remain in use until age a, the negative of its derivative expresses the probability of destruction at age a. The life expectancy μ_i is defined as

$$\mu_i = \int_0^\infty a \frac{d\ell_i(a)}{da} da = \int_0^\infty \ell_i(a) da, \tag{9}$$

where the last expression above is obtained from the previous by integration by parts. In the simple case of death dominated by accidents, $\mu = \tau_1$ and units of a particular age tranche decrease in numbers exponentially at a rate equal to the life expectancy.

Every year $t = t' + a$, a certain number of deaths $d_i(t)$ occur, technology units that are scrapped in some way or another, while a number $\xi_i(t)$ of units are sold, both changing the total number of units in use,

$$\frac{\Delta N_i}{\Delta t} = \xi_i(t) - d_i(t). \tag{10}$$

While sales generate units of age zero, deaths decrease the number of units of all ages,

$$\frac{dn_i(a,t')}{dt} \Delta t' = n_i(0,t') \frac{d\ell_i(\mathrm{a})}{da} \Delta \mathrm{t}', \quad n_i(0,t') = \xi_i(t), \tag{11}$$

where for each age tranche between a and Δa (or production year between t and $t + \Delta t$), the number of deaths depend on the probability of destruction as well as on the number of units of that age (or production year) remaining, which decreases every year. The number of units in each age tranche originates from sales which happened in year t' (a years ago). Thus, in the continuous limit $\Delta t \to 0$, while the total number of units at time t depends on the number of units sold in the past that still remain at time t,

$$N_i(t) = \int_{-\infty}^{t} \xi_i(t')\ell_i(a)dt' = \int_0^{\infty} \xi_i(t-a)\ell_i(a)da, \tag{12}$$

the reduction in the number of units at year t due to deaths is the sum the number of units that remain in each age tranche and their probability of being destroyed precisely in year t,

$$d_i(t) = \int_0^{\infty} \xi_i(t-a)\frac{d\ell_i(a)}{da}da. \tag{13}$$

Both these expressions are *convolutions* of past sales with either the survival function or the death probability. If sales $\xi_i(t)$ are related in any way to the existing number of units, this produces a *self-correlation* of the number of units with itself in past years. I will show later that this is effectively the case, which restricts how fast the total number of units can change in the system.[5]

2.2. The birth of technology

The number of units of technology that can be built in a time span depends on the production capital and labour available at that time. The fraction of production capacity[6] for technology i, $\delta N_i(b,t')\Delta t'$, built in years between t' and $t' + \Delta t'$ stems from the construction of new production lines or the creation of firms in that year, as well as those created in all previous years b. After its construction, production capital will generate funds from the sale of the units it produces, which are reinvested into expanding the total production capacity by building new production lines. This production capital however also has a lifespan, a probability of failure and thus a survival function. Therefore, the production capacity increase $\Delta\delta N_i(b,t')\Delta t$ generated by a production line of capacity $\delta N_i(b,t')\Delta t$ of age b producing technology units of type i is

$$\Delta\delta N_i(b,t')\Delta t' = R_i(b)\delta N_i(b,t')\Delta t'\Delta b \tag{14}$$

where $R_i(\mathrm{b})$ is meant to represent the reinvestment schedule. $R_i(\mathrm{b})$ is the rate of increase of the production capacity due to sales $\xi_i(\mathrm{t'})$ in year t', b years ago, and will be described into more detail further. The size of an age tranche of the industry as it evolves with age b is

$$\delta N_i(b,t')\Delta t' = \delta N_i(0,t')m_i(b)\Delta \mathrm{t}', \quad m_i(b) = \exp\left(\int_0^b R_i(b')db'\right). \tag{15}$$

As opposed to $\ell_i(a)$, $m_i(b)$ it is not a decreasing function, but it increases initially, as the production capacity generated expands, before decreasing in later years when old production lines get decommissioned, its sales generating less funds for creating new production capacity than it costs to maintain itself (depicted in Figure 2). It must be an integrable function, the area under which $\Phi_i =$

[5] Note that in contrast to the birth function that I shall define further, $\ell_i(a)$ must be a strictly decreasing function of age otherwise dead units would come back to life.

[6] The production capacity is taken here to include both production capital and labour for simplicity.

$\int_0^\infty m_i(b)db$ converges. Furthermore, it is not a normalised function as is $-d\ell_i(a)/da$, because this process generates an increase in the total production capacity and, as we show below, $R_i(0)\Phi_i > 1$.[7]

With reinvestment schedule in the first year $R_i(0)$, the creation of new production capacity in year t'using the funds generated by sales at that time $t' = t - b$ is

$$\Delta\delta N_i(0,t')\Delta t' = R_i(0)\xi_i(\mathrm{t'})\Delta t' \qquad (16)$$

Therefore, in the continuous limit, the total production capacity at year t is the sum of all production capacity created in previous years from sales:

$$\delta N_i(t) = \int_0^\infty \xi_i(t-b)m_i(b)db, \qquad (17)$$

This is another convolution, the second half of the problem, which generates, if the number of units is related to sales, a second autocorrelation in the number of units. In the particular case where the production capacity is fully used and sales are exactly equal to the production capacity, the production capacity increases exponentially, at a rate that has yet to be evaluated. This expression is very similar in form to the 'renewal equation' in demography (see for instance Kot, 2001; Metz and Diekmann, 1980), expressing a time correlation of past birth rates with later birth rates, with a maternity function $m(a)$ and a survival function $\ell(a)$,

$$B(t) = \int_0^\infty B(t-a)m_i(a)\ell(a)da, \qquad (18)$$

In contrast to biology, for technologies, since units do not undergo pregnancy at age a with probability $m(a)$ and probability of survival to that age $\ell(a)$, the equation does not feature a product of the survival function and the maternity function, and the meaning of the birth function is different.[8]

3. An age structured model of technological change

3.1. Destructions replaced by constructions

In a model of competition, several technologies compete in the marketplace to produce the same good or service. In many contexts, the consumption of that service is completely indifferent as to which technology has produced it, for example with transport services provided by vehicles with petrol, electric or diesel engines. In that case, one can assume that the total demand is independent of the composition of the technology mix that supplies this demand. In this context, building a model of competition requires determining the flow of units from one category of technology to another, and

[7] Otherwise sales generate less production capacity than was used to produce the units sold.

[8] Although some species, such as ants and bees, have individuals that do not undergo pregnancy but do contribute to the survival of the colony through other means, and there the dynamics may be somewhat closer to those described in this paper.

then generalising this reasoning to create a closed system that conserves the number of units. This was done in earlier work (Mercure, 2012b), which demonstrated how one can construct and understand the structure of a model of technology substitution, summarised here.

In this model, the choice of consumers or investors was separated from the diffusion process, for clarity. Choices of consumers or investors is taken to mean what choices would be made if all options were available but not necessarily well known, and these are defined in terms of preferences in the comparison of each possible pairs of technologies. Given that despite the first choice of consumers or investors, those may not necessarily be available in every individual situations, consumers or investors may have to content themselves with their second or third choice.

Assuming that units of any age are replaced by new ones when they are removed from the system through destruction,[9] following this approach, I evaluate the number of units flowing from one arbitrary technology category j towards another category i. For this, I start with the total number of destructions in all vehicle categories, and find how many of those belong to category j. Out of those destructions in j, I evaluate those that were chosen by consumers to be replaced by technology i, a choice process described below.

Of these, only a fraction can be produced. This statement is not obvious, and I shall attempt to explain it here. The number of individual situations where a choice is made is large. The production capacity of a particular technology may not necessarily be able to supply the demand in every one of these situations, were the consumers to all simultaneously choose this technology, if the production capacity is not high enough to generate this number. Therefore, in a certain number of these situations, the option will simply not be available, and consumers will have to choose between the remaining options despite their best preference. The fraction of instances where this choice will be available with respect to the total number of choices being made corresponds to the fraction of production capacity of this technology with respect to the total production capacity. This can be understood through an analogy involving an ensemble of shops with a number of competing products on their shelves. Given the production capacity of each product's respective industry, most of the shops may not be able to stock units of all competing products, restricting the local choice of the customers who go to those shops. When customers have equal preferences for all products, the relative probability of the average customer choosing particular products corresponds to the *average* composition of the product choice in the ensemble of shops, which itself corresponds to relative production capacity of each product with respect to the total. Thus the fraction of units of technology j, chosen to be replaced by technology i, that can actually be replaced by units of i corresponds to the fraction of the total production capacity that produces technology i.

[9] i.e. this only means that old units do not come back to life. Note that the nature of the ownership of these technology units, and whether they change ownership, is not important, which enables to make complete abstraction of second-hand markets.

As presented in earlier work (Mercure, 2012a, 2012b), I define consumer preferences in terms of the pairwise comparison of technologies as follows: when investors wishing to replace old units are faced with a choice between two technologies, I take a probabilistic approach where a fraction F_{ij} of consumers choose one technology while the rest F_{ji} choose the other, and therefore $F_{ij} + F_{ji} = 1$. This choice need not be fixed in time, since of course preferences and costs continuously change, in particular with technological learning. A list of technology is then explored in terms of this matrix by performing all possible pairwise comparisons. Thus, if some investors on average prefer j to i, some of them may still prefer a third option k to j, and so on. This generates an exhaustive (probabilistic) ranking of technologies based upon which flows in all directions can be evaluated. Thus the overall result of choices generates the ultimate driver for diffusion

The flow of units from categories j to i is summarised by the following, which is read from right to left:

$$\Delta N_{j\to i} = \begin{pmatrix} Fraction\ of \\ prod.capacity \\ belonging\ to\ i \end{pmatrix}_i \begin{pmatrix} \text{Consumer} \\ \text{prefs} \end{pmatrix}_{ij} \begin{pmatrix} Fraction\ of \\ units\ destroyed \\ belonging\ to\ j \end{pmatrix}_j \begin{pmatrix} Total \\ Destr. \end{pmatrix}_{tot}. \quad (19)$$

Accounting for the total change originating from flows in both directions, ΔN_{ij}, the sum of which generates the total change produced ΔN_i by the combined interaction between one technology and every other is

$$\Delta N_{ij} = \Delta N_{j\to i} - \Delta N_{j\to i}, \quad \Delta N_i = \sum_j \Delta N_{j\to i} - \Delta N_{j\to i}. \quad (20)$$

This construction enables to define an age structured demographic model of technology.

3.2. The age structured model

Eq. (20) can be written in terms of the production capacity $\delta N_i(t)$ and deaths $d_i(t)$:

$$\Delta N_{j\to i} = \left(\frac{\delta N_i(t)}{\sum_k \delta N_k(t)}\right) F_{ij} \left(\frac{d_i(t)}{\sum_k d_k(t)}\right) \left(\sum_k d_k(t)\right) \Delta \mathrm{t} \quad (21)$$

The production capacities and death numbers at time t can be replaced by convolutions of the sales:

$$\Delta N_{j\to i} = \left(\frac{\int_0^\infty \xi_i(t-b) m_i(b) db}{\sum_k \int_0^\infty \xi_k(t-b) m_k(b) db}\right) F_{ij} \left(\int_0^\infty \xi_i(t-a) \frac{d\ell_i(a)}{da} da\right) \Delta \mathrm{t} \quad (22)$$

Note the symmetry between the production side and the destruction side of this equation. There is, effectively, a high similarity between both processes. The difference however is fundamental: while $\ell(a)$ is a strictly decreasing function of age, $m(b)$ both increases and decreases. The decreasing nature of $\ell(a)$ generates destruction, while the increasing part of $m(b)$ generates production.

However, in order not to have an indefinitely increasing production capacity, $m(b)$ must also decrease again at high values of b, maintaining the function integrable, generating decreases in the production capacity when sales decrease, reflecting the gradual depreciation and wearing out of the production capital.

Eq. (20) with eq. (22) provides an expression for exchanges of units between categories in absolute numbers. However, the total number, the carrying capacity, could be changing, requiring either units that are brought in that do not replace deaths, or deaths that are not replaced. In the more common case of a total number K increasing, this is met by technology production following the relative production capacity:

$$\Delta N_i^{\uparrow} = \left(\frac{\int_0^\infty \xi_i(t-b)m_i(b)db}{\sum_k \int_0^\infty \xi_k(t-b)m_k(b)db}\right)\left(\frac{\Delta K}{\Delta t}\right)\Delta t, \qquad (23)$$

where choices need not be involved.[10] Meanwhile in the second less common case, the decrease in K is met by the relative rate of deaths,

$$\Delta N_i^{\downarrow} = \left(\frac{\int_0^\infty \xi_i(t-a)\frac{d\ell_i(a)}{da}da}{\sum_k \int_0^\infty \xi_k(t-a)\frac{d\ell_k(a)}{da}da}\right)\left(\frac{\Delta K}{\Delta t}\right)\Delta t \qquad (24)$$

Assembling these expressions together, one obtains an expression too large to write here, summarised by

$$\Delta N_i = \sum_j \Delta N_{ij} + \Delta N_i^{\uparrow}, \;\; or\; \Delta N_i = \sum_j \Delta N_{ij} + \Delta N_i^{\downarrow} \qquad (25)$$

When terms are replaced in eq. (25), the resulting large expression corresponds to the demographic model of technology expressed in terms of the full sales history. This model can also be expressed uniquely in terms of sales, where $\xi_i(t) = \sum_j \Delta N_{j\to i} + \Delta N_i^{\uparrow}$:

$$\xi_i(t) = \sum_j \left(\frac{\int_0^\infty \xi_i(t-b)m_i(b)db}{\sum_k \int_0^\infty \xi_k(t-b)m_k(b)db}\right)F_{ij}\left(\int_0^\infty \xi_i(t-a)\frac{d\ell_i(a)}{da}da\right) + \left(\frac{\int_0^\infty \xi_i(t-a)\frac{d\ell_i(a)}{da}da}{\sum_k \int_0^\infty \xi_k(t-a)\frac{d\ell_k(a)}{da}da}\right)\left(\frac{\Delta K}{\Delta t}\right) \qquad (26)$$

This expresses how sales at any time are constrained by *sales in the past* through convolutions, generating self-correlations of the sales, in other words, present sales correlated to the amounts of sales in the past, within and between categories. Since sales are autocorrelated, and that the addition of units corresponds to sales and removals to deaths, it implies that the absolute numbers of units are

[10] Adding here a factor F_{ij} can be done but is secondary: even if new units are not chosen exchanges can occur through the exchange term.

self-correlated as well. Therefore, changes in the numbers of units cannot change faster than is allowed by the self-correlation, which as we demonstrate next, is given by the width in time of the functions $\ell_i(a)$ and $m_i(b)$. Going any further requires evaluating all the convolutions, which requires knowledge on sales $\xi_i(t)$, survival functions $\ell_i(a)$ and birth functions $m_i(b)$.

3.3. Convolutions

Eq. (25) in its full form, or alternatively eq. (26), appear rather unconstrained and uninstructive. Since they are recurrent, these equations are more constrained in the behaviour of their possible solutions than they seem. Eq. (25) in full form expresses technological change between technology categories in terms of respective sales of those technologies. These sales are convolved with the functions $m_i(b)$ and $d\ell_i(a)/da$. It is well known in signal processing theory that convolutions of functions with bounded kernels (Figure 2 *left*) yield slightly modified functions that are *smoothed* with respect to the original, where (high frequency) sharp changes have been suppressed.[11] The ‘cutoff’ value at which frequencies are suppressed, the sharpness limit, corresponds to the *width* in time of the kernel.[12] This is also the *correlation length* of the smoothed function. For symmetrical normalised[13] kernels of similar widths, the convolution of a function leads to very similar results since a similar frequency cutoff occurs, even if the kernels have different shapes, and the same high frequencies are similarly suppressed. If a kernel is not normalised, it either amplifies the signal (its integral is greater than one) or damps it (its integral lower than one). If both kernels are not normalised but of similar width, the convolutions will yield results which are close to multiples of each other, with proportionality factor the relative area under the kernels. Finally, if the kernels are not symmetrical functions, as is the case here, a time offset may appear between the two results.

The first kernel, the birth function $m_i(b)$, has the following property,

$$R_j(0)\int_0^\infty m_i(b)db = R_j(0)\Phi_j > 1, \tag{27}$$

which reflects the growth of the production capacity through reinvestment. The second kernel, $\ell_i(a)$, is normalised by definition (expressing a eventual but certain death):

$$-\int_0^\infty \frac{d\ell_i(a)}{da}da = 1. \tag{28}$$

In the case of a uniform probability of death through time (a constant instantaneous force of death $p_i = 1/\tau_i$), $\ell_i(a)$ would have the form of an exponential decay of width $\mu_i = \tau_i$, the statistical life expectancy of units, and

[11] i.e. a `low-pass' filter.
[12] In this case both $m_i(b)$ and $d\ell_i(a)/da$; the wider the kernel, the lower the frequency cutoff and the more smoothing occurs.
[13] The area under a normalised kernel equals one.

$$-\frac{d\ell_i(a)}{da} = \frac{\ell_i(a)}{\tau_i}. \tag{29}$$

For survival functions of slightly different shapes, this may still hold approximately:

$$\ell_i(a) = \exp\left(\sum_k \frac{a^k}{\tau_{ik}^k}\right), \quad \frac{d\ell_i(a)}{da} = \ \ell_i(a)\left(\frac{1}{\tau_1} + \frac{a}{\tau_2^2} + \frac{a^2}{\tau_3^3} + \cdots\right), \tag{30}$$

with terms of ever decreasing importance. Taking this approximation, the number of units of j coming to death can be approximated to a simple quantity

$$\int_0^\infty \xi_i(t-a)\frac{d\ell_i(a)}{da}da \approx \frac{1}{\tau_j}\int_0^\infty \xi_i(t-a)\ell_i(a)da = \frac{N_i(t)}{\tau_j}, \tag{31}$$

where, as was shown with eq. (13), the second integral corresponds to the actual number $N_i(t)$ of units still in use.

In a case where the width of the second kernel, the birth function $m_i(b)$, is similar to the width of the survival function $\ell_i(a)$ (or alternatively the death function $-d\ell_i(a)/da$), the convolution of sales by one or the other of these functions will not be very different, but rather approximately proportional. Conversely, if the widths are very different, they *cannot* in any way be proportional or even similar. The width of the birth function is related to the survival function of the capital and labour used for production, the production lines, which may have, in some situations, a similar time scale. Assuming that this is so, and since $-d\ell_i(a)/da$ is normalised, then the convolutions with $m_i(b)$ and $-d\ell_i(a)/da$ are approximately proportional, and the proportionality factor is $R_i\Phi_i$ (with $R_i = R_i(0)$):

$$\begin{aligned} R_i\int_0^\infty \xi_i(t-b)m_i(b)db &\approx -R_i\Phi_i\int_0^\infty \xi_i(t-a-t_0)\frac{d\ell_i(a)}{da}da \\ &\approx \ R_i\Phi_i\frac{N_i(t-t_0)}{\tau_j} \approx R_i\Phi_i\frac{N_i(t-t_0)}{t_j}, \end{aligned} \tag{32}$$

where t_i is a new timescale relating to the growth rate of the production capacity. The factor $R_i\Phi_i > 1$ originates from the fact that production lines generate more units than was required to generate the funds used for their own construction. Therefore one has that $t_i = \tau_i/R_i\Phi_i$, a shorter timescale for the growth of production than for destruction. This *must* be the case otherwise the industry does not regenerate some of its components which gradually go out of business by producing more slowly than units get destroyed. The additional time offset t_0 appears due to the differing degree of asymmetry of the kernels, moving the functions $N_i(t)$ forwards or backwards in time slightly with respect to one another. The degree of symmetry difference between the kernels is limited and the time offset cannot be very large; in fact it is smaller than the width of the kernels, and I omit it henceforth.

3.4. Approximating the Lotka-Volterra equation

These approximations can be directly used to significantly simplify eqns. (22) and (25). Replacing each convolution by its associated approximation,

$$\Delta N_{j\to i} = \left(\frac{\frac{N_j(t)}{t_j}}{\sum_k \frac{N_k(t)}{t_k}}\right) F_{ij} \left(\frac{\frac{N_i(t)}{\tau_j}}{\sum_k \frac{N_l(t)}{\tau_l}}\right)\left(\sum_l \frac{N_l(t)}{\tau_l}\right)\Delta\mathrm{t}, \tag{33}$$

which is exactly the result obtained previously (Mercure, 2012b). Defining the average frequencies $\bar{t}^{-1}$ and $\bar{\tau}^{-1}$,

$$\frac{1}{\bar{t}} = \frac{1}{K}\sum_k \frac{N_k(t)}{t_k}, \quad and \quad \frac{1}{\bar{\tau}} = \frac{1}{K}\sum_k \frac{N_k(t)}{\tau_k}, \tag{34}$$

the flow becomes

$$\Delta N_{j\to i} = \left(\frac{\bar{t}}{t_j}\frac{N_j(t)}{K}\right) F_{ij} \left(\frac{\bar{\tau}}{\tau_j}\frac{N_i(t)}{K}\right)\left(\frac{K}{\bar{\tau}}\right)\Delta\mathrm{t} \tag{35}$$

while the term concerning increases in K becomes

$$\Delta N_i^{\uparrow} = \left(\frac{\bar{t}}{t_i}\frac{N_i(t)}{K}\right)\left(\frac{\Delta K}{\Delta t}\right)\Delta\mathrm{t} \tag{36}$$

Using a new matrix A_{ij} summarising all time constants, the total changes become

$$\Delta N_i = \left[\sum_j \frac{N_i N_j}{K}\left(A_{ij}F_{ij} - A_{ji}F_{ji}\right) + \frac{\bar{t}}{t_i}\frac{N_i(t)}{K}\left(\frac{\Delta K}{\Delta t}\right)\right]\frac{\Delta t}{\bar{\tau}}, \quad A_{ij} = \frac{\bar{t}\bar{\tau}}{t_i \tau_j}. \tag{37}$$

This is the Lotka-Volterra equation again. The replicator dynamics equation (4) can be obtained using the chain derivative:

$$\frac{dN_i}{dt} = K\frac{dS_i}{dt} + \frac{dK}{dt}S_i, \tag{38}$$

and obtain

$$\Delta N_i = \left[\sum_j S_i S_j \left(A_{ij}F_{ij} - A_{ji}F_{ji}\right) + \frac{\bar{t}}{t_i}S_i\left(\frac{\Delta K}{\Delta t}\right) - S_i\left(\frac{\Delta K}{\Delta t}\right)\right]\frac{\Delta t}{\bar{\tau}}, \tag{39}$$

which, if the t_i do not differ significantly from the average $\bar{t}$, reduces approximately to

$$\Delta N_i = \sum_j S_i S_j \left(A_{ij}F_{ij} - A_{ji}F_{ji}\right)\frac{\Delta t}{\bar{\tau}}, \tag{40}$$

This replicator dynamics equation has an anti-symmetric exchange matrix $\alpha_{ij} = A_{ij}F_{ij} - A_{ji}F_{ji}$. This equation is the one used in (Mercure, 2012a) to evaluate changes in the power sector technology mix of *FTT:Power*. Note that the two matrices used, A_{ij} and F_{ij}, separate the demography from the decision-making processes into independent considerations. It thus enables to introduce various types of decision-making assumptions into the same model of technology dynamics (e.g. investor behaviour under uncertainty or adaptive dynamics).

4. Interpretation of the Lotka-Volterra scaling parameters

4.1. Constraints and applicability of the Lotka-Volterra model

This calculation determines the constraints under which the general demographic model of technological change falls back onto the more specific empirical Lotka-Volterra equation:

1- The birth and death functions must have similar approximate widths in time
2- The dominant destruction mechanism must be close to a simple exponential
3- The area under the birth function for technology i, Φ_i, times the reinvestment schedule R_i, must be greater than one for the technology type to be able to replicate itself.

One then finds that $R_i\Phi_i$ determines the growth time constant in terms of the lifetime: $t_i = \tau_i / R_i\Phi_i$, where

$$\frac{1}{t_i} = \frac{R_i(0)}{\tau_i}\int_0^\infty \exp\left(\int_0^b R_i(b')db'\right)db, \tag{41}$$

with $R_i(b)$ a rate of reinvestment schedule in a production line of age b. Thus it is unsurprisingly the profile of reinvestment that determines the magnitude of the rate of growth of the production capacity t_i. Thus in order for the industry to grow, such that $t_i < \tau_i$, one must have that

$$R_i\Phi_i = R_i\int_0^\infty exp\left(\int_0^b R_i(b')db'\right)db > 1, \tag{42}$$

But what do $R_i(b)$ and $m_i(b)$ mean? $R_i(b)$ is related to the reinvestment of a fraction of the income of sales back into a production line as it ages, or alternatively in a finance context, the ability of borrowing money given the current success of the firm defined by the magnitude of its sales. There comes a point where particular production capital is not kept working but is gradually taken down to be replaced by something else. However, during its lifetime, this capital will have produced a large number of units each of which the sale will have generated income, a fraction of which will have been reinvested and will have expanded its capacity, such that it will have been able to produce more units, the greater amount sales of which will have generated ever more income and so on. In a situation of unconstrained sales, this leads to a simple exponential growth. However, the production capacity does not work forever but depreciates and ages, preventing an exponential increase to infinity of its capacity unless sales do the same, decreasing if sales decrease. While in biology the birth function $m_i(b)$ is the age specific average number of offspring per female in her limited lifetime, in the technology context it is a reflection of the multiplier effect of sales onto the production capacity and of its limited lifetime, or alternatively, the multiplier effect of the cumulative success of a firm onto its ability to borrow money for expanding its capacity.

The conditions listed in this section generate strict constraints that provide insight determining which systems may be modelled using the Lotka-Volterra set of equations (LVEs):

1- If the kernels have very different widths, the LVEs are not appropriate. This occurs if the life expectancy of the production capital is much longer or much shorter than the life expectancy of the produced units.[14]
2- The LVEs assume death rates proportional to the numbers of existing units. This approximation is equivalent to a uniform probability of destruction at any time. For technologies where the destruction factor is strongly limited by something else than accidents or random technical failures, a more elaborate model should be used.[15]
3- The producing firms must have an intended propensity towards expansion, and must reinvest enough profits to expand their production capacity, which will only decline if sales decline due to a lack of competitiveness. In a case where a firm has made a decision not to maintain a technology under production despite that it is profitable, the Lotka-Volterra model breaks down.

This clarifies under which constraints the Lotka-Volterra model can be used. In evaluating the evolution of the market shares of firms for a particular market, the technology unit used in the Lotka-Volterra equation is crucial. The units must be service producing technologies (e.g. ovens, power stations, vehicles, lighting devices), not the service itself (e.g. a piece of bread, a kWh, a transport service, light) or long-lived infrastructure (e.g. houses or buildings, roads, airports, sets of transmission lines, bridges) likely to be maintained for lengths of time beyond foreseeable future.

[14] E.g. the mobile phone industry, in which phones have very short lifetimes, or infrastructure industries where the capital, e.g. houses, roads and bridges, have much longer lifetimes than the firms building them, potentially maintained forever.

[15] E.g. mobile phones, where the decision to scrap is more related to the contract structure than to the wearing out of the product.

4.2. Interpretation of scaling parameters

The interpretation of τ_i is the life expectancy of technology units, which may be calculated using a survival function, and must be considered as a statistical lifetime. As detailed in (Mercure, 2012b), it gives rise to the technology turnover $\bar{\tau}$, a constant controlling the overall rate of change.[16]

The interpretation of $t_i = \tau_i R_i \Phi_i$ and $\bar{t}$ is more subtle. $R_i(b)$ is the reinvestment schedule, expressing a rate of production capacity increase that can be obtained from the fraction of profits on sales that is reinvested, the capital cost of new production capacity and the operation and maintenance cost of existing production capacity.

$$R_i(b) = \frac{Income_i(b) \times Faction_i}{CapitalCost_i(b) + O\&M_i(b)} \frac{[\$/unit\ Tech/year]}{[\$/unit\ Prod.Cap.]}, \qquad (43)$$

$R_i(b)$ is positive in early years and becomes negative in later years, where the operation and maintenance costs of ageing production capacity exceeds the income on sales and profits become negative. $R_i(b)$ need not be greater than one, as it is an accumulation of capital faster than its depreciation that generates an increase in production capacity, which is expressed by $m_i(b)$, or alternatively, Φ_i. Meanwhile, the parameter Φ_i expresses the multiplier effect of industry growth starting from individual units of production capacity. Thus, the longer the life of production capacity, or the higher the reinvestment fraction, the faster the growth pace of the industry becomes, expressed by a shorter growth timescale t_i. $\bar{t}^{-1}$ expresses the average rate of growth across the sector. The rate of profit making scales with the number of units produced per unit time. For long construction projects, ${t_i}^{-1}$ can be seen as proportional to the inverse of the construction time.

As indicated in detail in (Mercure, 2012b), it is interesting to note that growth timescales in eq. (40) only ever appear as ratios with the average $\bar{t}$. Therefore, if within a sector, it highlights that differences between the rates of growth of the production capacity of various technologies are important, their absolute value cancels out and does not influence the overall rate of change, which is controlled by the average scrapping rate $\bar{\tau}$. In particular, the rate of return on investment scales with the rate of construction (the inverse of the lead time), where a firm may in some cases be operating on specific construction projects without immediate income. As for example may happen in the power sector, this may restrict the rate of growth (the parameter ${t_i}^{-1}$) proportionally to the rate of construction, and that faster growing types of technologies can fill in gaps in the market faster than slow growing firms. Where other parameters are similar for different technologies, the ratio $\overline{t/t_i}$ becomes proportional to the ratio of the inverse lead time (rate of construction) with respect to the average inverse lead time (average rate of construction). This can simplify dramatically the

[16] Note that $\bar{\tau}$ need not be *constant* in time, but evolves if the relative frequency of technologies with different life expectancies change. In a case where shorter lived technologies penetrate the market, $\bar{\tau}$ shortens and the system accelerates, indicating a faster average turnover.

parameterisation of a Lotka-Volterra model down to lifetimes and lead times while remaining a credible model.

4.3. Example with a constant reinvestment schedule

These properties can be clarified by using the simplest possible example, a situation perhaps of seemingly unrealistic nature, but which depicts the nature of the results given above. Assuming that the reinvestment schedule is of a constant value R_i up to an age $\hat{b}$, after which it becomes $-R_i$

$$R_i(b) = \begin{cases} R_i, & 0 \leq b \leq \hat{b}_i \\ -R_i, & b > \hat{b}_i \end{cases}, \qquad m_i(b) = \begin{cases} e^{R_i b}, & 0 \leq b \leq \hat{b} \\ e^{R_i(2\hat{b}_i - b)}, & b > \hat{b} \end{cases} \tag{44}$$

where $m_i(b)$ is a continuous function with a maximum at $e^{R_i \hat{b}_i}$. Eq. (41) then generates

$$\frac{1}{t_i} = \frac{1 - e^{R_i \hat{b}_i}}{\tau_i}, \qquad R_i \Phi_i = 2e^{R_i \hat{b}_i} - 1 \tag{45}$$

In order for the industry to grow ($\tau_i > t_i$), one must have that $R_i \Phi_i > 1$. This will occur if $R_i \hat{b}_i > 0$, which is always true if there is a period of positive reinvestment that occurs, in other words if more money is reinvested than the threshold necessary to just maintain the existing production capacity in operation (that threshold being $R_i = 0$). Whenever this is the case, the growth rate is larger than the death rate.

5. Discussion: the demographic phase in technology transitions

Starting from the picture of (Geels, 2002), the process of technology transitions could be thought of as going through two different phases. This is depicted in Figure 3. New technologies originates from small, erratic, cumulative incremental innovations that gradually gain coordination as inventors and firms get to grips with understanding their own market and figuring out what is possible technically. This is shown with small randomly oriented arrows, with three colours indicating three innovations generating roughly the same service, or *societal function*. Many trials and errors generate experience and learning that gradually determine the successful direction to take. Once this happens, a better defined technology in a particular socio-technical context begins to gain momentum of diffusion, and enters what I will call the *demographic phase*. At this point, the growth rate is determined *both* by: (1) consumer preferences (in terms of the respective advantages and flaws of competing technologies) and related socio-technical context and its evolution, (2) the timescales of birth and death, or technology turnover. In a situation of very clear and favourable consumer preferences and socio-technical evolution, the diffusion becomes limited by the birth rate of the new technology, and by the death rate of the old technology being replaced. The birth rate cannot be faster than the rate of investment into production capital and labour, due to the magnitude of the income and associated financial flows, while the death rate cannot be faster than a certain lifetime associated to either the technical wearing out of units or to their *sunk costs*.

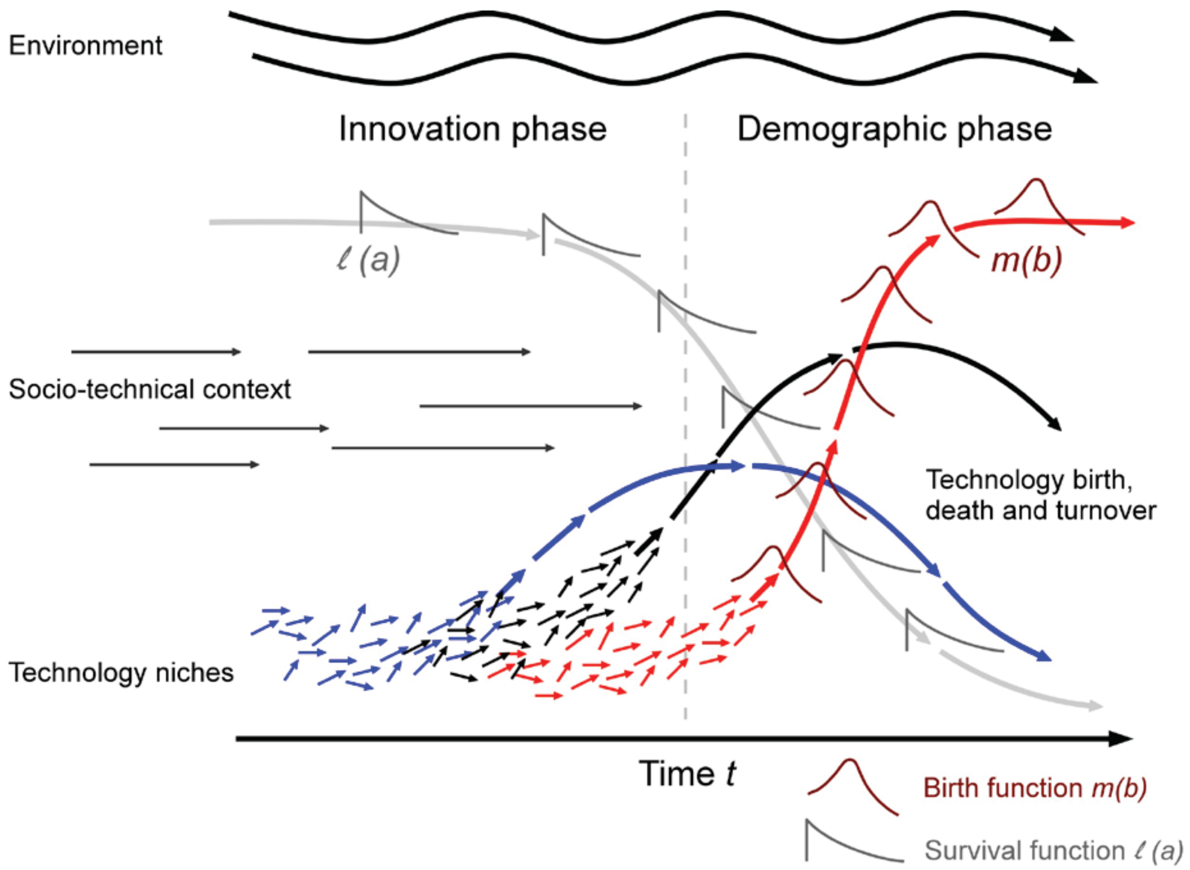

Figure 3: Illustration of the demographic phase of technology transitions, adapted from (Geels, 2002). Small arrows represent small incremental erratic innovations, during the innovation phase, which gradually gain coordination and momentum before diffusion takes place, entering the demographic phase. One technology is in decline (gray), disappearing at a maximum rate related to its survival function $\ell(a)$. One technology initially gains market shares at the expense of the one declining (blue), but is in time beaten in the race by another (black), which in turn is overtaken by yet another technology (red). The maximum growth rate is related to the birth function $m(b)$. The socio-technical context, consumer preferences and the environment generate selection mechanisms driving market share exchanges between technologies.

The innovation phase is difficult to model in a forecasting context, as this would require knowing the unknown, inventions that have not yet been invented. Therefore, it is difficult to describe innovation quantitatively beyond the picture by (Geels, 2005). However, when technologies enter the demographic phase, once they are well defined, modelling their evolution becomes straightforward, given a model of technology choice and knowledge of the birth and survival functions $\ell(a)$ and $m(b)$, or alternatively the life expectancy and the rate of reinvestment into production capital and labour of all competing technologies. Henceforth the applicability of the model becomes affected by either the possibility of new innovations appearing later into the picture, which cannot be predicted, or whether the conditions enumerated in section 4.1 remain met.

The key property that produce these limitations on the possible rates of growth and decline of technologies is that of *self-correlation*, where the number of units (or market shares) of a technology depends on itself in the past, the extent of which is defined by the functions $\ell(a)$ and $m(b)$. This self-correlation determines the overall rate of change of technology, the technology turnover. This rate of change is the key property to understand in contexts where technological change is important, notably in climate change mitigation. In climate change mitigation, the extent of climate change will be determined by future cumulative emissions, closely related to the moment when emissions will peak (if at all). Unless society is willing to accept or the economy able to afford a significant amount of early scrapping of technology (decommissioning technology much before its payback time), even in scenarios of strong policy incentives for change, this moment is critically determined by the rate of technology turnover, which is produced by this self-correlation.

6. Conclusion

This work has demonstrated that the origin of the empirical observation of the applicability of the Lotka-Volterra model of competition dynamics to technology diffusion originates from demographic principles applied to technology. I have created an age structured model of technology demography, using life expectancies and birth rates, and have created a complex model that, given the right conditions, using an approximation, falls back onto the form of the Lotka-Volterra model of competition. This operation has demonstrated the origin of the scaling parameters of the Lotka-Volterra model, the timescales of technology diffusion, in terms of *demographic* properties of technology, namely their birth rates and life expectancies.

The calculation presented however generates more insight than the simple correspondence of the Lotka-Volterra system to demography. While every previous quantitative use of the Lotka-Volterra for modelling technology diffusion has remained empirical and without clear justification, the calculation presented here explains *why* the Lotka-Volterra actually describes well systems of competing technologies at all. It moreover clarifies under which conditions it applies. Meanwhile, this paper gives meaning of the timescales of technology population dynamics suggested as a very general principle in the evolutionary economics literature and evolutionary game theory. The reasoning was broadened in order to connect to other descriptions of technology diffusion, in particular that of socio-technical systems and the multi-level perspective. I have defined a *demographic phase* of technology diffusion which, after technologies have emerged in protective niches, the seeds of diffusion, appropriate changes in the environment can enable to grow and invade the technology landscape.

This presentation clarifies the meaning of the scaling constants of the Lotka-Volterra model that enables its parameterisation without prior empirical measurement, difficult to do in cases where only small amounts of data is available. This tends to be the case precisely in the cases that are of most interest, namely when exploring the diffusion potential of new technologies under different assumptions concerning the market environment such as policy. This model enables to build models of technology based onto *S*-shaped diffusion curves and to parameterise them using known properties of the technologies and those of their respective production industries.

Finally, this work expands significantly the theoretical description of the approach used in the *FTT* family of technology models, including *FTT:Power*, which is meant to create a paradigm shift to conventional overall cost optimisation and the social planner assumption. As described in (Mercure, 2012a), the current standard calculation of greenhouse gas emissions using cost-optimisation models is a conceptually flawed concept, which could lead the climate change mitigation research and climate policy communities in error. This opens up a new avenue for quantitative technology modelling which could generate insight in many fields of research.

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The role of politics and the state in sustainable transitions: The rise and fall of offshore wind in Norway

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1. Introduction

Whilst the development of a new renewable energy industry has accelerated in EU in recent years the development in Norway has been at a virtual standstill (Hanson, Kasa, & Wicken, 2011, p. 234). This standstill has been explained by considering a lack of the same drivers in Norway as those present in many EU countries, and it has been hard to identify the motivation for building a large new renewable industry in Norway (Hanson et al., 2011, pp. 233-244). Firstly, nearly all electrical power in the ordinary grid in Norway comes from hydropower (Hanson et al., 2011, pp. 147-152) with only a small share of production coming from onshore wind. Hydropower is a dispatchable energy source meaning that energy security has rarely been a major issue in Norway. Finally, whereas the financial crisis could be seen as an opportunity to create jobs in the renewable energy industries in those countries affected by the economic downturn (Perez, 2013), unemployment has arguably not been a major concern in Norway. However, a few years ago there was a strong push from both political and industrial actors to build a large, domestic offshore wind industry in Norway. Despite these ambitions for a domestic industry, only 2.3 MW of capacity has so far been constructed off the Norwegian coast. This paper intends to explore why this is so.

In a study of the technological innovation systems for offshore wind in the UK, Germany, Sweden and the Netherlands, Jacobsson and Karltorp (2012) identified a lack of technology-specific market formation policies in Sweden and the Netherlands. Similarly, Hansen and Steen (2011) found a lack of a home market as an important barrier to innovation in the Norwegian offshore wind industry. Offshore wind is a very expensive source of electricity production, each kWh costing about twice what is produced from onshore wind (Kaldellis & Kapsali, 2013). In many countries, investment support is therefore too low for investors to realize offshore wind projects (Hansen & Steen, 2011; Jacobsson & Karltorp, 2012; Söderholm & Pettersson, 2011). Thus, it would be reasonable to assume that the lack of incentives such as feed-in tariffs and policies for marked development has blocked the development of offshore wind in Norway. However, the studies referred to above have made less of an effort towards understanding the causes of these blocking mechanisms. In other words, they describe the problem (what), but not what has caused the problem (how and why). The aim of this paper is to further the understanding of innovation processes by exploring the development of policies affecting offshore wind in Norway. This will be done by exploring which actors shape these policies, and how and why they go about doing so by asking: How did the Norwegian policy environment for offshore wind develop between 2007 and 2012, why did it develop in this way, and which actors or groups of actors influenced this development?

1.1. Conceptual framework

Explaining why some technologies or industries develop in some places and not in other has often been the starting point in many studies of technological innovation systems (TIS). One of the ambitions of the TIS approach is to describe what is actually achieved within an innovation system by focusing on functions, and by doing so, provide policy makers with recommendations through insights into system strengths and weaknesses. Moreover, the TIS framework provides researchers with a tool to identify feedback-loops involving different functions, providing valuable insights into how different functions can affect each other within a given system. The output of such studies will often be concrete policy advice that goes beyond the usual market failure recommendations, but address systemic problems related to innovation and diffusion of particular renewable energy technologies. Examples of weaknesses identified in TIS analyses include a lack of feed-in tariffs (Jacobsson & Karltorp, 2012), a lack of market formation (Suurs & Hekkert, 2009) a lack of variety (Bergek & Jacobsson, 2003), or a lack of qualified engineers (Jacobsson & Karltorp, 2012). It is then often assumed that government can address these system weaknesses through social policy.

A functional explanation such as the one employed in the technological innovation systems approach implies that we can attribute 'needs' to a society or a social system (Benton & Craib, 2011, p. 38). However, it is impossible to show that these needs must be met, or must be met in a particular way. Benton and Craib therefore argue that rather than talking about needs, it is possible to talk about 'conditions for existence'. These conditions do not cause action or change, but creates the opportunity for such action or change (Benton & Craib, 2011, p. 91). This line of thinking is similar to what Geels (2004) calls windows of opportunity, observed through a multilevel perspective on system transitions.

The concept of niches, regimes and landscapes introduced in the multilevel perspective (MLP) is a conceptual framework that, similarly to TIS, has seen a rapid development within the innovation literature in the last decade or so. This framework is very much inspired by new institutional theory and focuses on the interactions between systems, actors and what is referred to as rule-regimes (Geels, 2004). The principle idea with a multilevel perspective is to view the dominating regime within a broader context called the landscape level, whilst at the same time considering the relationship between the niches within the regime and the regime itself. Rules and regimes provide stability by guiding perceptions and actions. However, changes on the landscape level such as climate change may put pressure on the regime and cause internal restructuring (Geels, 2004). For expensive technologies such as offshore wind, protected niches will often be necessary for the technology to compete with the current dominant technologies, and to either enter into the current regime or force a regime change (Geels & Schot, 2007, pp. 408-417). At the same time, landscape effects such as climate change or financial crises may put pressure on a regime and depending on the particular circumstances may provide incentives for the support of new technologies. These landscape effects may therefore lead to what historical institutionalists refer to as 'critical junctures' (Thelen & Mahoney, 2010). Whereas institutions or rule-regimes can be seen as mostly constraining, critical junctures open up opportunities for actors to alter the trajectory of development (ibid.). As (Benton & Craib, 2011, p. 91) point out, these opportunities do not necessarily cause change but can create the conditions for actors to invoke change through agency and choice. The analysis should therefore consider how and under what circumstances agency is performed (Markard, Raven, & Truffer, 2012, p. 962).

Both the TIS and MLP approaches have been criticised for not paying enough attention to how policy is actually shaped. Transition management approaches assumes a normative path to a better system (Shove & Walker, 2007), which leads innovation scholars to assume an unproblematic translation of policy recommendations into innovation policies, with little role for politics (Flanagan, Uyarra, & Laranja, 2011). Put slightly differently, transition management enthusiasts may overestimate the possibility to ‘steer’ sustainable transitions, neglecting the political dimension of transitions (Meadowcroft, 2009). Consequently, sustainability researchers have focused too much on *policy* and much less on the *political* circumstances that make such policies likely (Meadowcroft, 2011). Smith, Stirling, and Berkhout (2005) point out that policy making occurs through negotiation between interested state and non-state actors, and argue for an increased focus on agency and power. Analyses of transition processes should therefore make attempts at understanding where (with whom) power resides, and how power and agencies are performed in transition processes (Markard et al., 2012). The literature certainly suggest that there is room for analysing the role of politics within the studies of sustainable transitions, and following (Smith, Voß, & Grin, 2010) this room exists both on the landscape, regime and niche level. Firstly, they stress that empirical studies should try to explain how and why individual agents are able to shape rules in desirable directions, both in the context of regimes and niches. Further, they argue that we need to understand which actors or networks give rise to such changes. Finally, they suggest that researchers should also explore how actions reflect changes on the regime and landscape level (Smith et al., 2010, pp. 445-446).

In order to address these needs for conceptual development, Kasa (2011, p. 60) proposes the use of the literature on “policy networks” as a way to make a connection between the literature on innovation systems and the literature on industry and energy policies. In writing about policy networks and state autonomy, Smith (1993) stresses that rather than policy being shaped through interest groups exerting pressure on the state, the state has its own interests. The impact of interest groups therefore depends on the interest of state actors and the types of relationships that exist in particular policy areas (Smith, 1993, p. 2). However, the state consists of multiple actors that are often not unified, and it can be difficult to identify the interest of the state due to conflict between politicians and bureaucrats, or between politicians. Policy may then often occur as a result of conflict within the state, and a state-actor will then try to form relationships with pressure groups that can help develop or hinder a particular policy. An important point is that policy networks occur when there is a potential for exchange of resources, and that government can exchange access to the policy process for group cooperation (Smith, 1993, p. 59). Finally, Smith makes a distinction between policy communities and issue networks. Policy communities often consist of only one actor representing each type (i.e. state actor, interest group). Access to the community is therefore highly restricted, and there will be a high degree of consensus among the members. The advantage for the state to develop policy communities is that it reduces conflict, keeps an issue off the public agenda, and produces more stability. However, external pressure (or landscape effects) may force the government to draw in other groups (Smith, 1993, p. 72). In such circumstances, it can be difficult for a state actor to maintain a closed community as several state actors may have an interest. The network may then develop into an issue network, with a large membership, open conflict between members, and with many members with little knowledge to exchange and thus little influence on the policy process.

The theory on policy networks suggest that in order to understand which actors or networks contribute to shaping rules, and how these actors are affected by changes at the landscape level, empirical studies of sustainable transitions should also consider the interest of different state actors. The development of policy communities often occur around policy areas where the state has or has had big ambitions (Kasa, 2011, p. 63). It is therefore relevant to consider the petroleum industry in Norway, which is of considerable importance to the Norwegian economy as a whole. As an illustration, in 2008 oil represented 60 per cent of Norwegian export revenues and 220 000 employees were indirectly connected to Norwegian petroleum activity (Ryggvik, 2010). Further, Ryggvik (2010) argues cogently how Norwegian policy makers have become looked into a very high investment level, and that this investment level is difficult to adjust. It was therefore a considerable challenge to policy makers when oil production from the Norwegian continental shelf saw a reduction by 40 per cent in the period 2000 to 2010 (OLF, 2010, p. 3). Interest groups related to production and consumption of fossil fuel are often well organized and have strong institutional ties to political parties, politicians and the bureaucracy, whilst groups with interests in an energy transformation are often less organized and more dispersed (Kasa, 2011, p. 59). Ryggvik underlines this point arguing that the national oil company Statoil has had particular strong ties to the Labour party (Ryggvik, 2010), which have held the Prime Minister position in the period 2005 to 2013. Mjøset and Cappelen (2011, p. 238) also makes the point that the centralization and consequently the influence of the oil block in Norway has increased in recent years as Statoil merged with the oil- and gas-division of Hydro in 2007. Thus, considering the big ambitions for offshore wind but with little to show for so far, a hypothesis could be that the state wanted to use offshore wind as a thermostat market for the offshore oil and gas supply industry, during a period of pressure on this industry.

1.2. Methods

In this paper it is argued for increased attention towards the role of the state and political interest rather than exclusively focusing on non-governmental interest groups and lobbying organisations. Further, it is argued that innovation research needs to have a more nuanced look at the role of policy networks. Finally, an effort is made towards reaching a better understanding of which way influence runs between the state and organisations. Given that the purpose of the paper is to identify how and why policy is shaped, a method of process tracing is deployed as this is the only way to separate correlation from causation (George & Bennett, 2005). In subsequent chapters, I describe the policy development in Norway through a narrative of the period 2007-2012 and trace decision-making processes for policy changes relevant to innovation and diffusion of offshore wind in Norway.

The narrative has first been constructed using data from policy documents and public reports. This data material has been complemented with data from the Norwegian media data base Retriever, performing extensive searches for relevant articles concerning offshore wind, energy and renewable energy policies. Finally, the data has been complemented with semi-structured interviews with key stakeholders related to offshore wind conducted at various locations in Norway in the period March to April 2013[1].

2. The rise of offshore wind in Norway

> *"Windmills at sea may be the new oil for Norway"* - Åslaug Haga, Minister of Petroleum and Energy, 05.02.2008

The above statement was made by the Minister of Petroleum and Energy when she received an expert report, named Energi21, detailing the long-term strategy for research, development and demonstration efforts for new energy technology in Norway. Coming from a ministry mainly preoccupied with oil, gas and hydropower, this was seen as a statement of intent and marked the beginning of a period with a range of events signalling a development of a Norwegian offshore wind industry. However, the positive mood around offshore wind can be traced back a couple of years prior to the Energi21 report in a report published by the Commission on low emissions in 2006. The mandate for this commission was to provide recommendations for how Norway could cut national emissions by 50-80 per cent by 2050, and offshore wind was included in a "technology package" that presented prioritized technologies (NOU 2006: 18).

At the same time as Energi21 took shape, the Government worked on a new white paper on Norwegian climate policy (St.meld. nr 34 2006-2007). Following the presentation of this document in 2007, the government parties and all opposition parties except the Progress Party signed the so-called climate settlement in January 2008. The purpose of the settlement was to ensure a long-term strategy for Norwegian climate policy, and it was to act as a premise for policy decisions related to climate change and renewable energy in the years to come. In the settlement, the parties agreed on a strategy for renewable energy technologies offshore, including a demonstration program for development and the introduction of new renewable energy technologies. This strategy underlined the need for designated R&D centres, and consequently led directly to the establishment of two centres for

[1] The interviewees are referenced by last name in the text. For full citations of the interviews see the reference list.

Environment-friendly Energy Research (FME) dedicated towards offshore wind in 2009 (Gulbrandsen Frøysa).

Although several Norwegian firms such as offshore sub-structure supplier Owec Tower had activities related to offshore wind as early as 2001, the real significant development came when the national oil company Statoil entered the offshore wind industry in 2007. In July 2007 Statoil joined several other large energy firms in a 20 million Euros investment in a floating wind concept developed by a company called Sway (Bergens Tidende, 12.07.2007). A few months later Statoil received 7.5 million Euros from state agency Enova in support towards the first full-scale floating turbine through the demonstration project Hywind. This investment by a major actor such as Statoil, combined with the numerous governmental reports, was seen as an important signal by the Norwegian industry (Hansen & Steen, 2012).

Towards the end of 2009, two more important events took place. Firstly, Sway received licenses from the Norwegian Water and Energy Resources Directorate (NVE) to raise a floating test tower off the coast of Karmøy and a 10 MW test turbine on land (for use offshore) in Øygarden outside Bergen. The company also received government funding from Enova as part of a financial crisis package. The floating test turbine at a scale 1:5 was raised in 2011. However, due to lack of additional funding, the 10 MW test turbine on land has yet to be realized.

One of the most significant events came when the authorities granted Vestavind Offshore a license to develop an offshore wind project called Havsul I, with 70 turbines off the coast of Møre and Romsdal. This license is still the only license that has been granted for a commercial offshore wind project in Norway. The total costs of the project was estimated to approx. 900 million Euros, and although Vestavind claimed that this was a competitive cost compared to projects in the UK, they still needed between around 200 million Euros in investment support from Enova or directly from the state (Bergens Tidende, 07.10.2011). Aside from the great enthusiasm the projects was met with by the Minister of Petroleum and Energy, the fact that such a costly project which clearly needed government financial support received a license was interpreted as a serious signal from the authorities that offshore wind would happen at a large scale in Norway (Ellingsen).

The developments in 2007 and 2008 were to some extent driven by climate change and renewable energy targets, evident in the climate settlement. However, this period was also characterised by decreased activity in the offshore petroleum sector, which directed a lot of firms´ attention towards offshore wind (Ellingsen; Hansen & Steen, 2011; Lygre). With the effects of the financial crisis coming into play in 2009, two important developments took place. Firstly, the government made available large funds towards new renewable energy as part of a green package, some of which was to be dedicated to offshore wind. Secondly, due to a decline in activity in the oil and gas sector and a significant drop in oil prices in 2009 and 2010, firms in the offshore industry were looking for alternative projects. As a consequence, the Ministry of Petroleum and Energy and the Ministry of

Trade and Industry went to great lengths to maintain employment levels in this industry. This was perhaps most evident in the Verdal region where the government provided funding for the development of a harbour that could accommodate offshore windmills (Adresseavisen, 04.09.2009), and by supporting the development of an industrial cluster in the region. Most significantly though, in late 2009 the international energy giant GE Energy purchased ScanWind, a Verdal based company producing wind turbines. Following the purchase, efforts were made to make sure GE Energy kept the turbine production in Norway and developed a test facility for offshore wind in Norway. One of the proposed locations for GE Energy's activity was Verdal, and the construction yard Aker Verdal joined a group of firms calling for funding for a demonstration facility in Verdal (Adresseavisen, 16.01.2010). The government responded and the Ministers of both Trade and Industry, and Petroleum and Energy made efforts to persuade GE Energy to choose Verdal (Adresseavisen, 06.10.2009). This was followed up by an allocation of roughly 1 million Euros from the Research Council to GE Wind Energy in December 2009. The efforts finally seemed to pay off as GE Energy announced in March 2010 that it would invest 80 million Euros in offshore technology in Norway. This would result in 100 jobs at a research and technology centre in Oslo, and an industry testing facility in Verdal (Dagens Næringsliv, 26.03.2010). Although actors from the industry were not impressed by the efforts from the authorities, the government took great pride in the announcement claiming that it was due to efforts made by the Minister of Petroleum and Energy, Riis-Johansen, and the Minister of Trade and Industry, Giske, that GE Energy decided to invest in Norwegian facilities (ibid.). Riis-Johansen even went as far as saying that "we will become world leaders on offshore wind" (Nordlys, 26.03.2010). One month later, in April 2010 the government announced a stimulus package for the yard industry in Verdal. The package was released following a drop in orders for the yard industry, but there would also be openings for this to benefit the offshore wind industry in Verdal (Dagens Næringsliv, 30.04.2010). Two months later, Aker Verdal received the first major contract for offshore wind foundations with the German firm RWE Innogy. With the contract, Aker Verdal received 15 million Euros in support from The Industrial Development Corporation of Norway, SIVA (Teknisk Ukeblad, 17.06.2010).

As this section shows, the period from 2007 to 2010 was characterised by a range of political signals mirrored by a range of industrial activities, with the most significant represented by Statoil, Vestavind Offshore and GE Energy. However, although these developments represented significant development both on a landscape level and on a niche level, the next section will show that this was not sufficient to destabilize the regime.

2.1. The need for learning arenas

The literature on innovation systems places learning processes at the centre of attention (Edquist, 2005, p. 184), and importantly recognizes that learning occurs through other activities than just research and development. Innovation and learning takes place mainly in firms, and these firms need learning arenas to demonstrate technology, develop competence, create legitimacy and foster further learning processes (Kemp, Schot, & Hoogma, 1998, p. 184). These learning arenas are in the transitions literature often referred to as niches (Geels, 2002; Kemp et al., 1998), and the need for facilitating a niche for offshore wind manifested itself through the call for offshore demonstration facilities.

One of the outcomes of the climate settlement in 2008 was the establishment of a 150 million demonstration program for the development and introduction of offshore energy technologies in 2009. However, the need for state funding towards test and demonstration facilities became visible already during the spring of 2008 when the companies StatoilHydro[2], Fred-Olsen and the energy company Lyse applied to Enova for about 4 million Euros that would help realize a subsea cable from the Hywind turbine. With the Enova funding, the cable could be expanded from a capacity of 2,3 MW to 15 MW (Teknisk Ukeblad, 12.08.2008). This cable would act as the infrastructure for a planned test centre for immature marine energy technology (Met-senteret) at the island of Karmøy (Stavanger Aftenblad, 24.05.2008), and would benefit other firms involved in offshore wind (Teknisk Ukeblad, 03.10.2008). However, Enova did not see the commercial justification for the state to invest in the project (Teknisk Ukeblad, 21.01.2009).

About a year later in 2009, the newly established research centre for offshore wind Nowitech voiced a need for a demonstration facility, this time around the number of firms operating in the offshore wind industry in Verdal (Trønderavisa, 26.06.2009). One of the problems was that Enova did not have the mandate from Ministry of Petroleum and Energy (MPE) to support this kind of facility, and there was no other agency that had the funds to support such a project. The MPE however responded that the technology was too immature to warrant a demonstration facility, and referred to the negative conclusion by Enova from the year before. MPE did however open the door for changing the mandate for Enova in 2012, once a new green certificates scheme was in place, so that the agency could also support these kinds of demonstration projects (Teknisk Ukeblad, 19.10.2009).

In 2010, a stronger lobby for offshore demonstration facilities emerged as the actors behind the initiatives in 2009 consolidated in an initiative called Demo2020. The organizations behind Demo2020 were two wind clusters located in Bergen (Arena NOW) and Trondheim (Windcluster Mid-Norway) and the two research centres located in Bergen (Norcowe) and Trondheim (Nowitech). The main objective was to overcome localization issues, pointed out by Enova a year earlier, and to propose a common plan to the authorities (Vik, 2010). The initiative proposed the building of 8 offshore turbines at a total cost of 300 to 500 million Euros (Bergens Tidende, 04.03.2010). The group also tried to get support from The Norwegian Confederation of Trade Unions (LO) and the Federation of Norwegian Industries for the initiative. During 2010, the initiators of Demo2020 managed to get the attention of the political opposition, which became evident in April 2010 when members of the

[2] The name StatoilHydro was the result of a merger between Statoil and Hydro in 2007. The name was later changed to just Statoil in 2009.

opposition in the Standing Committee on Business and Industry proposed the public funding of a test and demonstration facility, established by 2011. However, the governing parties turned the proposal down referring to Research Council Norway and Enova as the main instruments for developing new renewable energy technologies (Innst. 335 S 2009-2010).

A final initiative for the establishment of demonstration facilities grew out of a collaborative effort between energy giants Statoil, GE Energy and Lyse when they in April 2010 announced a collaboration on a demonstration facility for offshore wind power in the Rogaland region (NTB, 24.04.2010). The demonstration park would cost more than 40 million Euros, with half of the costs needed to be covered by the authorities. The turbines would be built in Verdal by ScanWind and would thus secure a high level of activity and development for some time. Several other Norwegian suppliers were also in the mix as both Owec Tower and Vici Ventus Technology (owned by Lyse) had applied for the construction of foundations.

Although things were looking good, there was still a degree of uncertainty concerning how the government would follow up the previous stated ambitions. There were concerns within the offshore wind industry that without significant efforts to develop a domestic wind energy market, GE Energy would move the production abroad (Adresseavisen, 26.03.2010). The lobbying for funding towards a demonstration centre therefore continued throughout 2010 with meetings between representatives from GE Energy, Aker Verdal, local politicians and the Minister of Trade and Industry, Trond Giske (Trønderavisa, 07.09.2010).

3. Decreased expectations

> *"There is no point for me to use many tax billions to build a wind farm at sea only for it to be at sea"* – Ola Borten Moe, Minister of Petroleum and Energy, 17.03.2011

In the beginning of 2011, there was a strong belief in the future among offshore wind actors based on the negative developments in the offshore oil industry. The leader of Scatec (part-owner of offshore wind company NorWind), Alf Bjørseth, stated in February 2011 that "I don't think it will be much fun working in the oil industry in the coming years" (Økonomisk Rapport, 10.02.2011). One month later, new petroleum discoveries and a new Minister of Petroleum and Energy proved to represent significant events affecting policies for the offshore wind industry.

However, the uncertainty around the prospects of a big offshore wind industry in Norway had emerged already in 2010 when the proposed demonstration facilities had failed to attract the governmental support that was needed. Much then relied on the outcome of the proposed project developed by GE Energy, Statoil and Lyse, and it soon became clear that this project could also only be realized with financial support from state agency Enova.

In late 2009, the government announced a change in the support scheme for new renewable energy that would involve the introduction of green certificates replacing the investment support scheme previously administered by Enova. This new scheme would be introduced in 2012, and due to the estimated prices on certificates, electricity prices, and high cost of offshore wind, it was clear that offshore wind could not be realised through this scheme. However, given the positive signals that had been issued by the government in various forms, there were still considerable expectations concerning the future role of Enova and the support for offshore wind (Ellingsen).

Firstly, in June 2009, a new law for production of offshore renewable energy was adopted in parliament (Ot.prp. nr. 107 2008-2009). With reference to the Energi21 process, the document stated that the Energi21 strategy would be followed up by the Research Council on R&D and by Enova on demonstration (Ot.prp. nr. 107 2008-2009, pp. 27-29). The R&D ambitions had been realized in the establishment of the research centres Nowitech and Norcowe, but there remained some uncertainty as to how financing of demonstration would be handled by Enova. For several years this uncertainty continued and as late as in April 2011 the Ministry of Petroleum and Energy stated that Enova would have activities within full-scale demonstration of new energy solutions (Prop 101 L 2010-2011), but that it had not yet decided how targets for these projects would be formulated, and that this would not become clear until a new agreement with Enova was made in 2012.

Much as a result of changing signals from the government and the general uncertainty around the support schemes for offshore wind, GE Energy announced in September 2011 that it would close down the production facility in Verdal. The decision did not only have consequences for jobs in Verdal, but it also sent a negative signal to the entire offshore wind industry in Norway about the future potential of this industry.

GE Energy was not the only company that relied on the support schemes for offshore wind, as also Vestavind Offshore followed the process around Enova keenly. Due to the continuing positive signals sent by the government, Vestavind Offshore had remained optimistic about the financing of Havsul I as late as January 2011. However, in March 2011 there were two important events that occurred within two weeks. Firstly, the government announced a new Ministry of Petroleum and Energy with considerably different politics than his predecessors (Ellingsen), and shortly after Statoil announced a major oil discovery in the Barents Sea. The former arguably had a negative impact on the government attention to offshore wind, as the quote in the beginning of this chapter also indicates, whilst the latter lead to increased optimism in the offshore petroleum supply industry (Dagens Næringsliv, 02.04.2011). At the same time, there was uncertainty around Enova, and in 2011 and 2012 Vestavind Offshore made a range of attempts at establishing a dialogue with both the Ministry of Petroleum and Energy and the Ministry of Trade and Industry. However, there was no political interest to meet with representatives from Vestavind Offshore (Ellingsen). State agency Enova did on the other hand show some interest and stated that they would be able to support the offshore wind project Havsul I given that they received “favourable political signals” (G. Buvik, email to B. Anfinnsen and

E. M. Hollfjord, 14 Dec 2011). However, it became clear in 2012 that these signals would not come. This was first made visible in the new agreement between Enova and MPE (St.meld. nr 21 2011-2012) and later in the annual government budget for 2013, presented in September 2012, when MPE announced that the conditions for building Norwegian offshore wind parks would be the electricity price and the revenues from green certificates (Prop. 1 S 2012-2013, pp. 168-171). As a consequence, the board of Vestavind Offshore declared in December 2012 that they had given up on the Havsul I project due to unfavourable conditions (Bergens Tidende, 05.12.2012). At the same time, a number of firms pulled out of the research centre Norcowe and the focus within the Windcluster Mid-Norway shifted from offshore to onshore wind.

4. Discussion

The previous chapter shows that offshore wind was high up on the political agenda in the period between 2007 and 2010. This articulated priority given to offshore wind was accompanied by a number of major industrial initiatives. Some of the more important events were the Havsul I project developed by Vestavind Offshore, the process around GE Wind Energy and other offshore firms in the Verdal region, and the establishment of two large R&D centres for offshore wind (the FMEs in Bergen and Trondheim). In trying to explain these developments, it is important to be aware of the wider context in which both political and industrial goals were shaped. Taking a multilevel perspective, three landscape effects put pressure on the energy regime in this period. Firstly, the climate crisis put pressure on the government to increase the renewable share of total energy consumption in Norway. This was visible both on an EU level, but also on a national level as it gave the political opposition the opportunity to put pressure on the government and make renewable energy a public issue. A second landscape effect was the global financial crisis that also affected Norwegian industry. The third landscape effect, which was to some extent accelerated by the financial crisis, was the decreased activity on the Norwegian continental shelf as a result of reduced oil prices and a lack of new petroleum discoveries. This affected in particular the amount of contracts available for the offshore supply industry in Norway. The combination of the two latter effects put pressure on the government to come up with policies that would ensure that the affected industries could maintain their levels of activity. With petro-maritime resources available from the declining offshore oil and gas industry, a large effort in offshore wind can be seen as a logical solution for the government to respond to the pressure from the landscape effects of peak oil and financial crisis. Offshore wind may, on the other hand, not seem like the most logical solution to meet pressure from the climate crisis to develop more renewable energy, given the immaturity of this technology and high costs of offshore wind. Moreover, the promises for offshore wind did not materialize in major policy changes as both Vestavind Offshore and GE Energy failed to attract the necessary state funding needed to realise their projects. Nor did

Enova receive the mandate from the Ministry of Petroleum and Energy to provide developers of offshore wind with significant investment support.

To understand how new technologies can emerge within protected niches and potentially disrupt dominant sociotechnical regimes, it is also important to understand how these regimes can be dislodged (Shove & Walker, 2007, p. 764). In her memoirs Åslaug Haga, the former leader of the Centre Party and member of the government coalition between 2005 and 2008, claimed that an "iron triangle" between the Ministry of Petroleum and Energy, the Ministry of Finance and the Prime Minister´s office blocked major policy changes in her period as a minister in 2007 and 2008 (Haga, 2012, pp. 294-296). In the same book, she states that there are powerful forces in Norway that want to maintain stability in the existing fossil energy regime (Haga, 2012, p. 251). Given the economic importance of the oil and gas industry in Norway, this is hardly a controversial statement. Yet, it may point to the existence of a closed policy community that has excluded a range of actors affected by the energy policies shaped within the community. One of the interviewees with good insights into the politics of energy policies in Norway stated rather bluntly that the relationship between the state and the hydropower lobby was very strong, and that their main lobby organisation Energy Norway in effect was a state interest organisation (Isachsen). The process concerning Enova's role in supporting offshore wind that unfolded in 2012 was a closed process involving state agency Enova and the Ministry of Petroleum and Energy where the latter very much determined the outcome of that process (Ellingsen). It could therefore seem to have been a policy community that has excluded key actors from the offshore wind industry from important policy processes affecting this industry.

The development of renewable energy policies on the other hand seems to have happened in more open networks. Chapter 3 showed how ambitions for renewable energy appeared within both the Ministry of the Environment and the Ministry for Petroleum and Energy, yet there seems to have been little coordination between the Energi21 process and the development of the white paper on climate policy from 2008. Targets for renewable energy became the source of several conflicts within the coalition government (Haga, 2012; Sølhusvik, 2012) and was also brought on to the public agenda by the political opposition. By contrast to the policy community shaping much of the energy policy, the actors with interests in renewable energy policies may not have had a great deal of resources to share with state actors in exchange for policy influence. With the Ministry of Finance also having a strong interests in the development of renewable energy policies (Kolbeinstveit, 2009; Sølhusvik, 2012), as well as a range of interest groups and NGOs (Tjernshaugen, 2011), the group of actors involved in shaping renewable energy policy in Norway resembles what Smith (1993) calls an issue network. Smith (1993, pp. 66-74) argues that the consequence of an issue network can be policy inertia, or constantly changing policy. Boasson (2011) presents evidence arguing for the latter by describing the development of changing policies for onshore wind in the period from 2002 and until the green certificates were introduced in 2012.

As suggested by former Minister Åslaug Haga, there are powerful forces resisting changes to energy policies in Norway. Smith (1993, pp. 101-135) shows through an example of UK agriculture policy how seeking a closed policy community can be an effective strategy for the state to resist policy change under pressure from external effects. The example goes on by showing that a strategy to resist change can be to accept some policy changes whilst maintaining the fundamental policy line (of agriculture support in this example). In the case of Norwegian energy policies, the important thing for the government under pressure from the landscape effects may have been to appear as if something was done, whilst at the same time maintain the current policy trajectory. The question then is if can see the positive developments for offshore wind from this perspective.

The establishment of Norcowe and Nowitech (FMEs) can be traced back to the climate settlement in January 2008 and the Energi21 report published one month later (Ellingsen). Whilst the former was concerned with climate policy and renewable energy explicitly, the latter was motivated by a goal to increase growth in the energy sector through R&D and development of new technology (St.prp. nr 1 2007-2008). Both processes concluded that a large R&D effort in offshore wind was required, and it can be difficult to identify which of these processes actually led to the establishment of the FMEs. However, the director of one of the research centres, Norcowe, identified the climate settlement as the direct cause of the FME strategy (Gulbrandsen Frøysa). Thus, the large R&D centres for offshore wind could be interpreted as a way for the state to react to the landscape effect of climate change without having to make other major policy changes.

When the NVE issued a license to Havsul I and Vestavind Offshore in 2009, supported by an enthusiastic Minister of Petroleum and Energy, the Ministry had a firm understanding of the costs needed to realize the project (Ellingsen). Although this event was interpreted by industry as a significant signal of intent from the government at the time, there were no obligations from the state to invest significant resources or to adopt new policies. The government support for Vestavind Offshore can then also be interpreted as what Edelman (1967) calls the symbolic uses of politics. Offshore wind was associated with large ambitions and presented as the new industry that would one day replace the oil adventure. Based on Himmelstrand (1960, cited in Edelman 1967), Edelman argues that the greater distance between a symbolic act and the people’s actual experience of the act heightens the emotional potency of the political act. One of the interviewees takes this argumentation one step further, arguing that offshore wind was promoted *because* of the immaturity of the technology and that commercial realization would be further into the future. Therefore, government appeared to be doing something radical about climate change without having to make major financial investments or significant changes in policy direction. This would also then ease the pressure to do something about technologies with more immediate potential such as onshore wind (Isachsen).

Landscape effects, state resistance to change and symbolic uses of politics can also act as useful analytical concepts to further understand why policies did not develop favourably for offshore wind in

2011 and 2012. Already towards the end of 2010, it started to become clear that the financial crisis had not hit Norwegian industry as hard as some had feared (OLF, 2010). Moreover, the petroleum discoveries in 2011 can be seen as significant landscape effects that removed the pressure from reduced oil activity. However, the negative signs for offshore wind began prior to the announcements of major oil discoveries in 2011. Moreover, it is difficult to identify any significant change in the landscape effect of climate change in 2011. Finally, it is hard to find a strong correlation between the political enthusiasm around Havsul I and Vestavind Offshore and the peak oil and financial crisis landscape effects. It has already been argued in this chapter that the support for Vestavind Offshore can be explained by the state wanting to resist policy changes whilst appearing to act on landscape pressure through the symbolic use of politics. We should therefore then also consider the nature of the relationship between Vestavind and the state actors. As the previous chapter shows, there was a great deal of uncertainty around what role Enova would play in supporting offshore wind once the green certificates were introduced in 2012. This was formally a process between Enova and the Ministry of Petroleum and Energy. The outcome of this process was important for the realisation for Havsul I (Ellingsen), and Vestavind Offshore consequently made several attempts at opening a dialogue with the MPE on this subject. However, it is difficult to see what resources Vestavind Offshore had to exchange with the MPE, and Vestavind consequently had very limited access to this policy process.

5. Some early conclusions

The narrative of the period from 2007 to 2010 presented in chapter 2 shows how a window of opportunity opened for the offshore wind niche to enter into the hydropower dominated energy regime in Norway. This opportunity for new conditions for existence for offshore wind came much as a result from pressure on the regime through landscape changes such as financial crisis, reduced petroleum activity and reduced oil prices, and climate change. Further, using concepts from the policy analysis literature on policy networks and the symbolic uses of politics, it has been argued in chapter 4 that it may have been through a strong state interest in maintaining stability during this period of regime pressure that offshore wind was positioned high up on the political agenda in this period. However, the pressure on the regime eased in 2011 and 2012, and the state could continue pursuing the interest in maintaining activity in the offshore petroleum supply industry without introducing disruptive policies. As a consequence, it seems as if the window of opportunity for offshore wind closed in this period as offshore wind disappeared from the political agenda.

This study shows that the offshore petroleum industry has had a significant impact on the offshore wind industry in Norway, which is a finding also supported by Hansen and Steen (2012). However, the discussion in chapter 4 also alludes to possible conflicts between different new renewable technologies. Kasa (2011, p. 58) reminds us that different actors within the production of renewable energy will also compete over influence on the policy process and that it will not always be the most legitimate technologies that end up on the political agenda. Chapter 4 suggests that the investments by the state in research centres for offshore wind was influenced by the symbolic uses of politics and that this support came at the expense of onshore wind. Other possible conflicts can be found between the large national effort to develop CCS and the attention given by both state actors and NGOs to other renewables in Norway (Tjernshaugen, 2007). How efforts to promote different renewable technologies may impact on each other would therefore be an interesting avenue for future research.

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Climate change and the slow reorientation of the American car industry (1979-2018): An application and extension of the Dialectic Issue LifeCycle (DILC) model

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Abstract:

This paper uses the Dialectic Issue LifeCycle-model to analyse the co-evolution of the climate change problem and strategic responses from the American car industry. On the one hand, the longitudinal and multi-dimensional analysis investigates the ‘problem stream’ (activities analysis from social movements, scientists, wider publics and policymakers to define and place climate change on agendas). On the other hand, it analyses the ‘solution stream’ and socio-political, economic and innovation strategies from US automakers. We develop and use a novel mixed methodology with a quantitative analysis of various time-series and an in-depth qualitative case study, which traces interactions between problem-related pressures and industry responses over five periods. We conclude that US automakers are slowly reorienting towards low-carbon technologies, but have not yet fully committed to comprehensive development and marketing. The paper not only applies the DILC-model, but also proposes two elaborations: a) the continued diversity of technical solutions creates uncertainty which delays strategic reorientation in phased 4 of the model, b) firms may develop radical innovations for political and social purposes in early phases of the model.

1. Introduction

Climate change is one of the 'grand challenges' facing society, requiring low-carbon innovation in many sectors and industries. This paper addresses low-carbon innovation and reorientation in the car industry, with a focus on the United States. The innovation studies literature contains many papers on various low-carbon automotive innovations, e.g. hydrogen and fuel cell vehicles (Bakker, 2010; Van den Hoed, 2005; 2007; Budde *et al*., 2012), hybrid electric vehicles (Dijk and Yarime, 2010), battery-electric vehicles (Johnson, 1999; Dijk *et al*., 2013), and biofuels (Duffield *et al*., 2008).

Despite its achievements, this literature has three shortcomings. First, because of the focus on technical solutions, it tends to reify the problem of climate change, assuming that we all agree about its existence and importance. It ignores that societal problems have dynamics of their own, related to interpretation, mobilization and agenda-setting, and that these dynamics influence the development and diffusion of technical solutions (through social sense of urgency, political will, and public policies that shape both the selection environment and technology generation). We therefore suggest that analysts should focus on the dynamics of both the 'solution stream' and the 'problem stream', and their interactions (Kingdon, 1984).

Second, because of the strong focus on innovation strategy (R&D, patenting, technology partnerships) much of this literature pays too little attention to broader corporate strategy, which is also concerned with economic positions, markets, political pressures, and social reputations. Particularly with regard to 'grand challenges', it is likely that firms-in-industries use a wide array of strategies to shape how problems are discussed and politically addressed. Because innovation strategy is embedded in wider corporate strategy, we suggest that an understanding of low-carbon industry reorientation should not only look at innovation strategies, but also at political, socio-cultural (framing) strategies, and economic positioning strategies, and their interactions.

Third, much of this literature focuses on single innovations such as fuel cell vehicles (FCV), hybrid-electric vehicles (HEV), battery-electric vehicles (BEV), and biofuels. Such a focus fails to acknowledge that firms (particularly in the car industry) face multiple possible low-carbon technologies, and that this diversity creates strategic uncertainty. It also pays insufficient attention to the possibility that low-carbon technologies may compete for public and political attention, for funding, and for market share. An implication of these complexities is that studies of single low-carbon innovations may be too optimistic in their future assessment. We therefore propose that studies of green industry reorientation should analyse multiple innovations.

In two previous papers (Penna and Geels, 2012; Geels and Penna, 2013), we developed a Dialectic Issue LifeCycle (DILC) model, which addresses the first two problems, but not the third one. The paper has two aims. The first, empirical, is to apply the DILC-model to climate change and the American car industry to assess the degree to which automakers are engaging in low-carbon reorientation. This assessment will analyse both the 'problem stream' (pressures resulting from various social groups) and the 'solution stream' (technical innovations by automakers), and the specific interaction mechanisms over time (using an ideal-type model with different phases). It will also address the multitude of strategies used by automakers, and how they relate to innovation strategy. And the analysis will cover multiple technologies, including possible 'hype-disappointment cycles', which refer to ups and downs in attention to new technologies.[1] For the car industry, Geels (2012a) intuitively suggested successive hype-cycles in the last 20 years (Figure 1). We will investigate this suggestion and the implications for low-carbon reorientation.

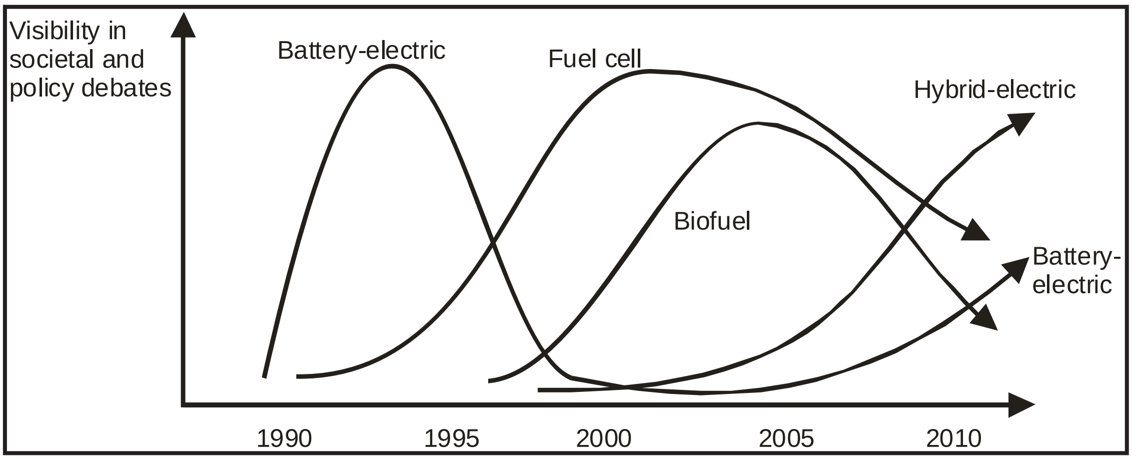


Figure 1: Hype-disappointment cycles for green propulsion technologies (Geels, 2012: 477)

The second aim is to make two conceptual elaborations to the DILC-model, taking advantage of complexities of the climate change case, which differs from previous case studies on responses of US automakers to the problems of air pollution (Penna and Geels, 2012) and car-safety (Geels and Penna, 2013). In these previous studies, the technical solution was relatively clear, and the main problem was to overcome the resistance of the car industry to strategically reorient towards them. For climate change, however, it is less clear what the 'best' solution is because of the diversity of green innovations. In fact, views about 'best' solutions have experienced ups and downs in successive hype-cycles, creating strategic uncertainty and fear of betting on the wrong horse. The first conceptual elaboration is therefore to investigate how the diversity of possible solutions influences the phases in the DILC-model.

The second elaboration relates to the early development of BEVs (early 1990s), which is sooner than the ideal-type DILC-model posits for issue lifecycles. To explain this deviation we will complicate the often-used distinction between 'symbolic' industry responses to social problems (political and framing strategies) and 'substantive' responses (technology development). We will propose that industry actors may use technology for political and framing purposes in early phases of the DILC-model. This reinforces the point that innovation strategies are often embedded in broader corporate strategies.

[1] We use the notion of hype-cycles, which was introduced by Gartner consultancy, in a descriptive rather than evaluative (derogatory) sense. 'Hypes' also have performative and productive effects, because they attract attention and funding to new technologies (Bakker, 2010). We therefore use 'hypes' and 'attention-cycles' interchangeably.

The paper is structured as follows. Section 2 discusses the DILC-model and identifies three underdeveloped aspects. Section 3 discusses the quantitative-qualitative methodology. Section 4 presents the results of our quantitative analysis. Section 5 presents an in-depth longitudinal case study of climate change and the American car industry (1979-2012), and assesses likely developments until 2018. Section 6 draws conclusions about the stage of the climate change issue lifecycle and the degree of low-carbon reorientation of American automakers. It also proposes two conceptual elaborations of the DILC-model.

2. The Dialectic Issue LifeCycle (DILC) model

The Dialectic Issue LifeCycle (DILC) model conceptualizes interactions between an evolving social problem and responses from incumbent industries. Penna and Geels (2012) developed the DILC-model by combining insights from issue lifecycle theory (to conceptualize the dynamics of social problems) and innovation studies (to conceptualize the dynamics of technical 'solutions'). Geels and Penna (2013) enriched the DILC-model with insights from social movement, political science, public attention, issue management, corporate political strategy, and innovation management, to enhance the understanding of what goes on inside each of the five phases.

We qualified the DILC-model as *dialectic* to highlight the struggles between the build-up of problem-related pressures ('issue lifecycle') and responses from incumbent industry actors. Firms-in-industries tend to resist and contest the pressures related to social problems, because these mostly (especially in early phases) come from civil society and policymakers rather than consumers. Addressing these problems thus entails additional costs, while offering (at least in early phases) few commercial benefits. So, firms tend to resist addressing social problems to protect their vested interests. But pressures from public opinion, social movement organizations (SMO) or policymakers increase as issues progress through phases in the DILC-model, forcing firms to (gradually and reluctantly) develop more radical technical solutions.

The DILC-model incorporates a suggestion from Mahon and Waddock (1992:27) to distinguish between symbolic strategies action and substantive strategies. "Symbolic action involves attempts to 'frame' an issue. (…) Substantive action, in contrast, involves definitive moves that attempt to actually change or deal with the existing situation in specific, identifiable ways. It often demands the expenditure of resources (money, equipment, personnel, etc.) to minimally show progress in resolving the actual problem identified". The DILC-model also included their suggestion that firms initially tend to opt for symbolic action and later move towards substantive action when problem-related pressures increase. But we expanded the dimensions of strategy distinguishing four kinds: a) economic positioning strategies (supply chain management, operations management, marketing etc.), b) innovation strategies (product development, resource allocation, knowledge management), c) corporate political strategies (lobbying, financial contributions to political parties, constituency building etc.) and d) socio-cultural strategies (public relations, advertising, information campaigns). The first two strategies are oriented towards the economic task environment in which firms-in-industries operate, and the last two strategies towards the socio-cultural (or 'institutional') environment, in which industries are also embedded (Figure 2). The bi-directional arrows in Figure 2 indicate that firms-in-industries do not only *adapt* to pressures from the environments, but also actively aim at *shaping* those environments.

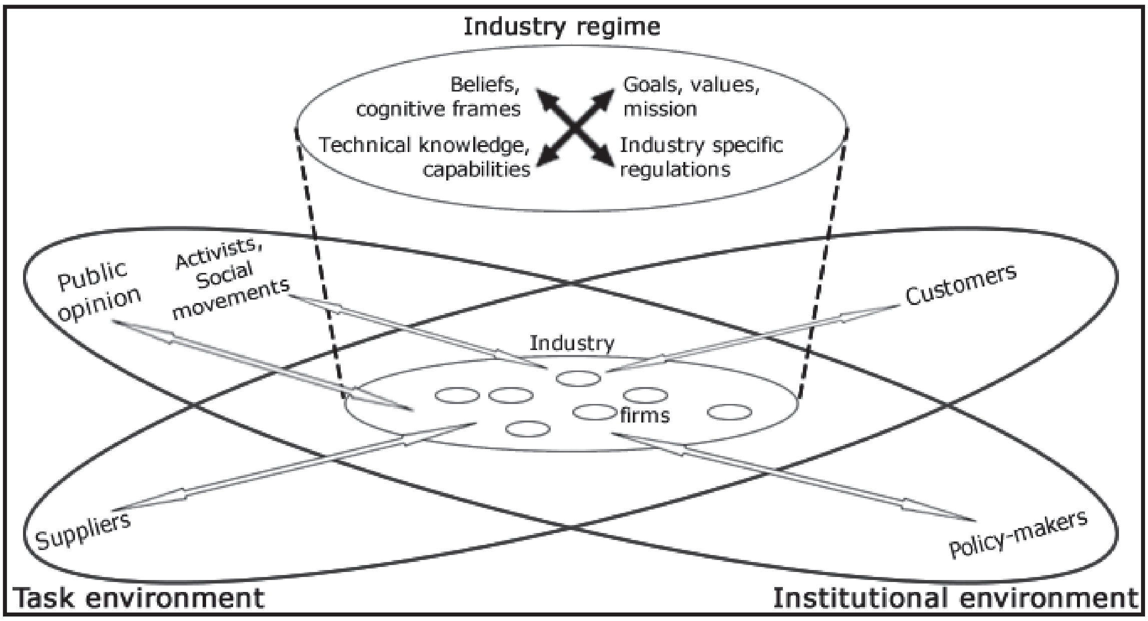


Figure 2: Triple embeddedness framework of industries (Geels, 2013)

Using the triple embeddedness framework (Figure 2), the DILC-model proposes that the first three phases of issue lifecycles primarily occur in the institutional environment. That is why firms primarily use socio-cultural and political strategies in the early phases, and some (mainly incremental) innovation strategy. In phase 1, the problem is first articulated by activists, concerned citizens, or researchers, who push for recognition by wider actors. Firms pay limited attention or downplay its importance with socio-cultural framing strategies. In phase 2, social movements are created who raise the profile of the problem and achieve some public attention. Firms respond defensively, by denying or contesting the problem ('symbolic actions'), by creating a 'closed industry front' vis-à-vis policymakers, or by engaging in incremental innovations. In phase 3, rising public attention pushes the problem onto the agenda of policy sub-systems, which is associated with specialists in the bureaucracy, congressional subgroups, interest groups and stakeholders. These actors will investigate the problem (through hearings and inquiries) and discuss possible solutions, which initially tend to stay close to the interests and expertise of the existing policy sub-system (True *et al*., 1999). On the one hand, incumbent firms will publicly defend the existing regime using political and framing strategies to influence public opinion and the policy sub-system. On the other hand, they may privately begin to explore possible radical solutions, to hedge against possible policy outcomes or changes in the economic environment.

In the first three phases, incumbent firms are reluctant to make substantial change to address the problem, because they are ‘locked in’ to industry regimes (Figure 2), which are industry-specific institutions that mediate actions and perceptions (Geels, 2013). The industry regime, which provides a third kind of ‘embeddedness’, consists of four ‘core elements’: 1) capabilities and technical knowledge, 2) identity and mission, 3) industry beliefs and mindsets; and 4) regulations and formal policies which shape economic frame conditions. Lock-in mechanisms for these core elements and lack of pressures from the economic task environment help explain why incumbent tend to fight, resist and downplay social problems in the early phases. If they (are forced to) acknowledge social problems, firms may move towards incremental solutions but will publicly resist substantial reorientation (and more radical innovation).

While the first three phases are mainly about socio-political mobilization, the issue lifecycle gathers a new dynamic in phase 4 and 5, when the problem spills over to the economic task environment (Geels and Penna, 2013). In phase 4, escalating public attention propels the problem into the macro-political arena (True *et al*., 1999), associated with Parliament, Congress and the government, where politicians may introduce radical legislation that substantially changes the economic frame conditions (e.g. taxes, regulations, standards, subsidies, investments). The problem then moves back to the policy sub-system, where implementation struggles between executive agencies and the industry are likely. In phase 5, the problem affects consumer preferences (because of changing views on appropriate behaviour or because of public policies), which creates market demand for radically new technologies.

Corporate attention to the problem intensifies in phase 4 and 5, and incumbent firms begin to develop and reorient towards radical (‘substantive’) responses. The reorientation towards radical innovations is a costly and risky process, which often proceeds through phases: a) hedging and exploration (starting in phase 3), b) strategic diversification (phase 4), accompanied by changes in some regime elements (technical capabilities and regulations), c) full reorientation (phase 5), accompanied by more foundational changes in belief systems and mission (March, 1991). While initial steps tend to be hesitant, reorientation may accelerate if leading firms experience first-mover advantages. If this leads to ‘jockeying for position’ and an innovation race, the initially closed industry front may open up.

Table 1 summarizes the co-evolution of problem-related pressures and industry responses during an issue lifecycle.

Phases	Dynamics of societal 'problems' and associated 'pressures'		Dynamics of 'solutions' and strategies of incumbent industries	
	Institutional pressures	**Task (economic) pressures**	**Framing, socio-cultural, and political strategies**	**Technology and innovation strategies**
1: Problem emergence and industry neglect	The problem first emerges when activist groups articulate concerns. Uncertainty about causes and consequences gives rise to framing struggles.	No specific pressure from task environment.	Constrained by the industry regime, incumbent firms do not recognize the problem, downplaying it through socio-cultural strategies.	Industry is 'blind' to the issue, and therefore no technology strategy is specifically deployed response to issue.
2: Rising public concerns and defensive industry responses	The social problem progresses when activists coalesce into a social movement that pushes the issue onto public agendas (Elzen *et al.*, 2011). Increasing public worries create credibility pressures on policymakers who perform symbolic actions (expressing concerns, creating committees).	Relative regime outsiders (e.g. suppliers, foreign firms, new entrants) begin to develop technical solutions in response to the increasing salience of the problem, which they perceive as an opportunity.	The industry perceives the problem as a potential threat to the existing regime, and creates a closed front and industry associations that contest claims from social movements and lobby policymakers (using political strategies).	If further denial of the problem damages the industry's reputation, particularly when regime outsiders are already working on solutions, firms begin to work on incremental technologies that stay within the bounds of the existing regime.
3: Political debates, controversies and defensive hedging	The issue moves to the next phase if rising public attention creates credibility pressures on policymakers, pushing the problem onto the agenda of policy sub-systems, where hearings and investigations are held.	The work by outside firms or suppliers on alternative solutions can undermine the argument from incumbent firms ('alternatives are not feasible'). Alternatives may also find a foothold in small market niches linked to 'moral customers' who are concerned about the issue.	To influence the debates, industry actors use political and framing strategies (e.g. emphasizing costs or technical complexity). They also argue that regulations are not necessary, because they will 'voluntarily' implement (incremental) solutions.	Incumbents portray radical solutions as unfeasible. For defensive reasons, industry actors may hedge and explore these alternative solutions in laboratories.
4: Formation and implementation of substantive policy and industry diversification	The shift to the next phase entails the problem moving onto the macro-political agenda, where politicians may introduce radical legislation. Policy implementation starts.	Regime outsiders lead developments targeted at the growing (but limited) 'moral consumer' market segment. However, concerns do not (yet) spill over to mainstream markets.	If legislation cannot be prevented, firms use lobbying and information strategies (e.g. release of technical studies) to influence the implementation of the new regulation, leading to implementation struggles. While some firms argue that radical solutions are still unfeasible, first movers may lobby for tougher regulations to raise costs for competitors.	Confronted with conflicting pressures from institutional and task environments, firms are likely to diversify and increase R&D investments to develop new capabilities in radical alternatives. Individual firms may break ranks, embrace the new technology more enthusiastically and 'jockey for position' in the growing market niche. This could cause cracks in the industry front and lead to an 'innovation race'.
5: Spillovers to the task environment and strategic reorientation	The move to the next phase entails the problem affecting mainstream consumer preferences. This happens when public discourses lead to changes in mainstream consumer preferences or when regulators substantially change the economic frame conditions (through taxes, incentives, legislation).		Incumbents reorient the industry regime towards the new markets, incorporating the alternative technology in economic positioning strategies. Addressing the problem also becomes part of the industry's core beliefs and mission, leading to further transformation of the industry regime	

Table 1: A Summary of the DILC-model in terms of problem-related pressures and industry responses

The five-phase DILC model is an analytical heuristic, which this paper aims to elaborate in two ways. First, the DILC-model implicitly assumes that there is *one* radical innovation to which incumbent firms reorient in the fourth and fifth phase. The existence of *multiple* technical solutions (as in the case of green cars) creates additional uncertainty and complicates this reorientation, because firms don't want to 'bet on the wrong horse'. To address this uncertainty, firms may use portfolio strategies to build capabilities in multiple technologies. It may be possible hedging (phase 3) lasts longer than in normal cases. So, a diversity of technical solutions may delay strategic diversification and full reorientation towards radical options (in phase 4 and 5).[2]

Second, we aim to nuance the distinction between 'symbolic' and 'substantive' firm strategies. The DILC-model mainly sees technological innovation as a substantive response, because it demands significant resource expenditure and is oriented towards the economic task environment. We aim to nuance this view by recognizing that technology can also be used for symbolic purposes (e.g. enhancing public reputations) and political purposes e.g. showing that certain options are unfeasible or that regulations are not necessary) in the institutional environment. "Carefully chosen displays of symbolism may circumvent the need for substantive change entirely. (…) Outputs [e.g. technologies], procedures, structures, and personnel can all signal that the organization labors on the side of the angels – even if these supposed indicators amount to little more than face work" (Suchman, 1995:588). Environmentally-friendly technical prototypes are common examples of symbolic or political use of technologies, because they signal to external stakeholders that firms are committed to solving the environmental issue. The implication is that firms may engage in radical innovation (e.g. prototypes) in early phases of issue lifecycles for symbolic and political reasons. This creates complications for the largely sequential view on technological reorientation in the current DILC-model (incremental innovation, hedging, diversification, full reorientation).

We will explore the two issues empirically in the case study, and return to them in section 6.

3. Methodology, data sources and epistemology

The case study focuses on climate change and responses of the American car industry (1979-2012). We selected the U.S. for reasons of feasibility and because we expect struggle and contestation to be particularly present in America because of confrontational relations between industry and policy/society. Our focus on the U.S. has two principal limitations. Firstly, foreign-owned car companies also operate and produce in the U.S. market. To address this limitation we include discussion of foreign car companies, which exert pressures on 'domestic' automakers. Secondly, American automakers operate in other parts of the world. We therefore also discuss global developments (e.g. climate change policies in Europe and Japan) as pressures on the American car industry.

We apply a combined quantitative-qualitative methodology (Geels and Penna, 2013). The quantitative analysis aims at identifying initial patterns of proxy variables through time, which are

[2] The continued co-existence of multiple technologies may make it difficult for a problem and solution to be 'coupled into a package' (Kingdon, 1984:21).

further explored with an in-depth qualitative analysis to identify causal relationships and mechanisms. We also use the timeseries to divide the whole period into shorter ones. The proxy variables are rough indicators and thus need to be used with some caution. For the quantitative analysis, we used the following proxies:

- For *public attention* we use the number of newspaper articles on climate change as proxy (Newig, 2004). We searched the *Nexis* database for newspaper articles (New York Times, USA Today, Wall Street Journal and Washington Post) with the keywords "climate change", "global warming" or "greenhouse effect" (and derivates) in their headlines.
- For policy-making activities *(*congressional attention) and policy-implementation activities (executive branch attention), we used climate-change related entries in the *Congressional Record* and the *Federal Register*, respectively.[3] We searched these publications in the *HeinOnline* database with the *same* keyword string as above.
- We used article count in the *Automotive News* (American ed*ition*) as a proxy for how much attention American automakers dedicated to climate change (same search string as above) and different drivetrain technologies. Ups and downs in industry attention can be used to identify 'technology hypes' (Bakker, 2010a). We distinguish four alternative vehicle technologies: (1) and hydrogen fuel cell vehicles (FCV), (2) battery-electric vehicles (BEV), (3) hybrid-electric vehicles (HEV), and plug-in hybrid vehicles (PHEV) (4) biofuel, ethanol, and flex-fuel vehicles (FFV), and searched for articles with keyword-strings related to each of them.[4]
- We use patents as a proxy for technical development by the auto industry. We searched the USPTO database with the *AcclaimIP*[5] patent search and analysis application. We searched for patents related to the four alternative vehicle technologies, and, additionally, for those related to advanced internal combustion engine (a-ICE) technologies (e.g. improved fuel-injection systems, turbo charging, advanced valve management). Our search methodology follows Oltra et al. (2008) for the identification of 'eco-patents' on environmental technologies and 'green' products, which combines in the search string keywords and patent classes related to the focal-technology (see example in Table 2). This method allows for a reduction in 'noise' (i.e. exclusion of irrelevant patents, inclusion of relevant ones). We restricted our search to the three largest American car manufacturers (and their controlled subsidiaries): General Motors, Ford and Chrysler (the 'Big Three'). Duplicated patents were excluded.

[3] The *Congressional Record* publishes transcripts of hearings, debates and speeches and bill proposals, indicating evolving attention to issues. The *Federal Register* publishes regulatory agency's notifications and rules and (presidential) executive orders, two key types of policy-implementation action at the U.S. Federal level.
[4] Articles citing more than one technology were assigned to all cited technologies.
[5] https://www.acclaimip.com/ (accessed multiple times between 1/8/2012 and 12/4/2013)

Technology	*CobaltIP* search string	Keywords	Classes	Assignees
Hybrid-Electric Vehicles	((PSCLS:180/65.21 OR PSCLS:903) OR (TTL:(("hybrid vehicle" OR "hybrid electric vehicle" OR "hybrid propulsion" OR "hybrid powertrain" OR "hybrid powerplant") NOT "fuel cell")) OR (ABST:(("hybrid vehicle" OR "hybrid electric vehicle" OR "hybrid propulsion" OR "hybrid powertrain" OR "hybrid powerplant") NOT "fuel cell")) OR (ACLM:(("hybrid vehicle" OR "hybrid electric vehicle" OR "hybrid propulsion" OR "hybrid powertrain" OR "hybrid powerplant") NOT "fuel cell"))) AND AN:("general motors" OR "Delphi Technologies" OR "delphi technology" OR "gm global" OR "gen motors" OR "delco electronics" OR "Saturn Corporation")	"hybrid vehicle", "hybrid electric vehicle", "hybrid propulsion", "hybrid powertrain", "hybrid powerplant"	180/65.21 (and subclasses), 903 (and subclasses)	"general motors", "Delphi Technologies", "delphi technology", "gm global", "gen motors", "delco electronics", "Saturn Corporation"
	Comment: We searched for keywords in the patent's title (TTL), abstract (ABST) and claims (ACLM). The "AN" code searches the patent assignee field for certain keywords. The field code 'PSCLS' searches for patents with predefined *primary* parent class(es) and all subclasses under the specified parent class.	*Comment:* We excluded patents citing "fuel cell". The assignee restriction increases the confidence that the patents are related to car technologies.	*Comment:* The 65.21 subclass is for "hybrid vehicles" under the class 180 ("motor vehicles"). The class 903 is a specific class for HEV-related technologies	*Comment:* We included words related to General Motors and its controlled subsidiaries that are known to file most of the OEM's patents.

Table 2: Example of patent search string (HEV-related patents in the USPTO assigned to General Motors)

The resulting set was ordered according to the patent's *priority date*, which is the date of the first filing of a similar claim in *any* patent office, in order to better reflect the timing of the invention. To address the lag between filing and issuing a patent (which leads to a decline in the number of patents in more recent years), we divided the number of patents of interest per year by the total number of patents per year by the selected carmakers to arrive at a percentage index.

We also plotted the market share (relative sales) of the different green technologies in the U.S. market. A complication concerns figures for flex-fuel vehicles, which can be fuelled either with ethanol or gasoline or both, and thus may overestimate the share of 'alternative' fuel vehicles.

The quantitative analysis consists of two steps: (a) firstly, we performed a Quandt Likelihood Ratio test for unknown structural breaks (Stock and Watson, 2006), in order to identify significant breaks in the timeseries[6]; and (b) secondly, we triangulated these findings with a visual examination of the plotted timeseries and our substantive knowledge of key events in the case study to establish sub-periods.

While this quantitative approach allows for the identification of general patterns (structural break analysis and visual examination) and levels of association (correlation analysis), it does not

[6] Our tests included up to four lags (five restrictions) to account for autocorrelations, and were applied to the natural logarithm of the variables. All statistics' procedures were performed with Stata 12.

reveal causal relationships. To identify deeper *causation*, we also perform a longitudinal case study, which analyses interactions and processes in the institutional and task environments. Primary sources for developments in civil society are articles from newspapers and magazines (*New York Times*, *Wall Street Journal*, *Washington Post*, *Economist*). We also draw on the National Research Councils' and governmental reports (USEPA, CARB, USDoE, NHTSA), industry journals (*Ward's*; *Automotive News*), and publications by automakers and their trade association (financial reports, press releases, websites, advertisements, technical papers). In addition, we build on secondary accounts of different dimensions of climate change and the car industry: science, environmental movement and public opinion (Corfee-Morlot et al., 2007; Dunlap and colleagues); policy and legal developments (Duffield et al., 2008; Meltz, 2008); corporate cultural and political strategies (Doyle, 2000; Kolk and Levy, 2001;Luger, 2000); automakers' innovation strategies and technological developments (Abeles, 2004; Bakker (and colleagues); Budde et al, 2012; Dijk et al., 2013; Johnson, 1999; Kemp, 2005; Lutsey, 2012; MacCormack, 2005; Mondt, 2000; van den Hoed, 2005, 2007); broader industry contexts and financial dimensions (Ingrassia, 2010); environmental challenges facing the car industry (Sperling and Gordon, 2009). Drawing on various primary and secondary sources we aim to develop a comprehensive multi-dimensional analysis of the climate-change problem and car industry responses.

Epistemologically, we see the DILC-model as a heuristic tool to analyse temporal and multi-dimensional interactions between social problem dynamics and industry responses. The DILC-model is an ideal-type that stylizes and simplifies complexity. Weber (1949:89) characterized an ideal-type as a "conceptual pattern that brings together certain relationships and events of historical life into (...) an internally consistent system. Substantively, this construct in itself is like a utopia which has been arrived at by the analytical accentuation of certain elements of reality." As a style of theorizing, ideal-types "show us interconnections between elements, let us see how things influence each other in the pure case, so that we can detect their operation in the less pure conditions of the real world" (Becker, 2007:158). "All models by their very nature distort the reality they are intended to describe" (Hedström and Swedberg, 1998:15), and as such, we don't expect a perfect match between the ideal-type model and real-world complex case studies. Our research strategy is therefore to compare the real-world case study to the ideal-type and explain similarities and differences.

4. Quantitative results

Figures 3 present time-series for: a) public attention to climate change, b) Congressional attention and executive attention, c) attention by Automotive News, d) aggregated Alternative Fuel Vehicle (AFV) patents by the Big Three. Figure 4 presents time series for: a) attention by Automotive News to specific technologies, b) Big Three patenting of specific technologies, c) market share of AFV, d) market share of Electric Drive Vehicles[7] (EDV).

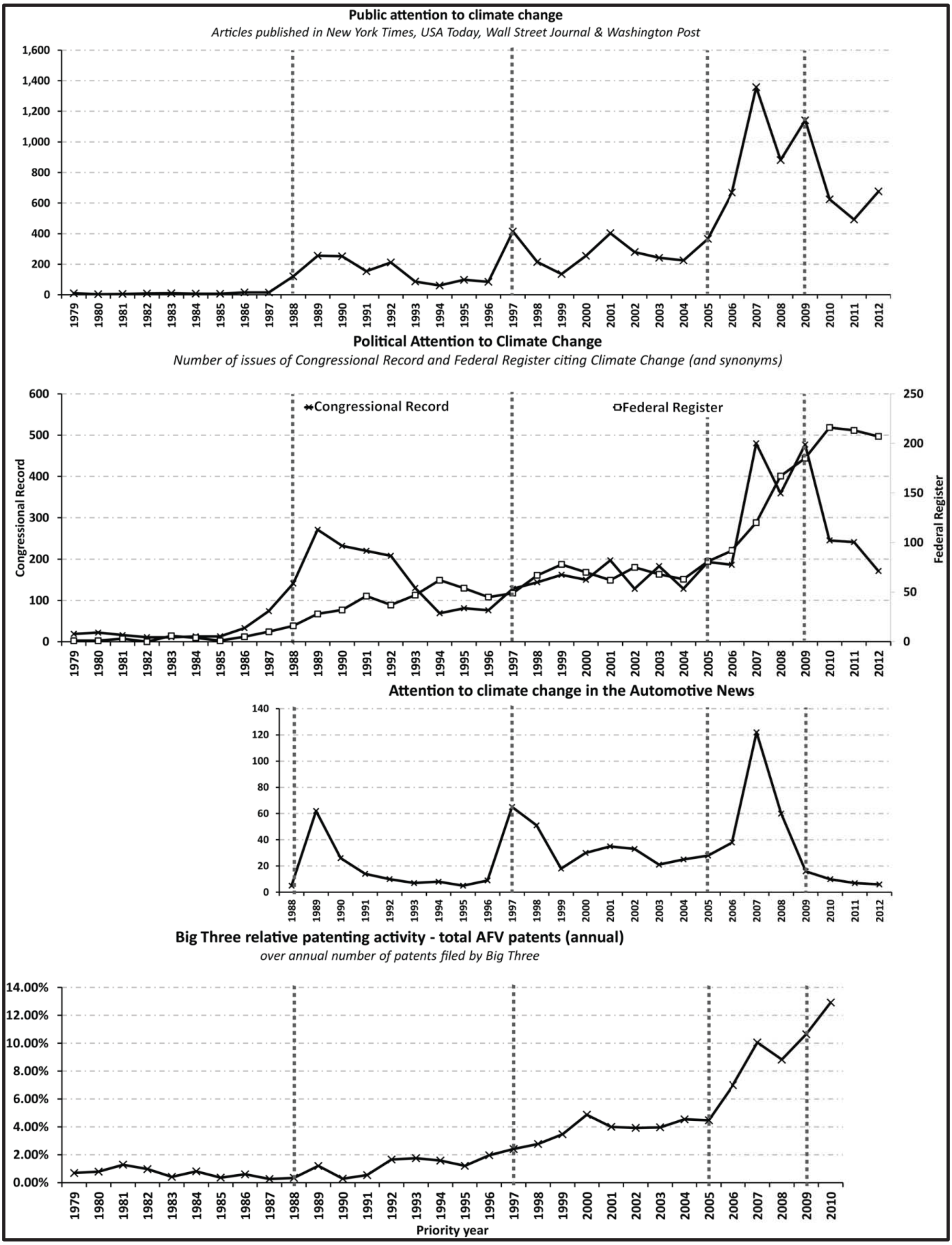


Figure 3 (a-d, top-down): Visual representation of proxy variables defined in section 3

[7] The EDV category comprises fuel cell vehicles (FCV), hybrid-electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV) and battery-electric vehicles (BEV).

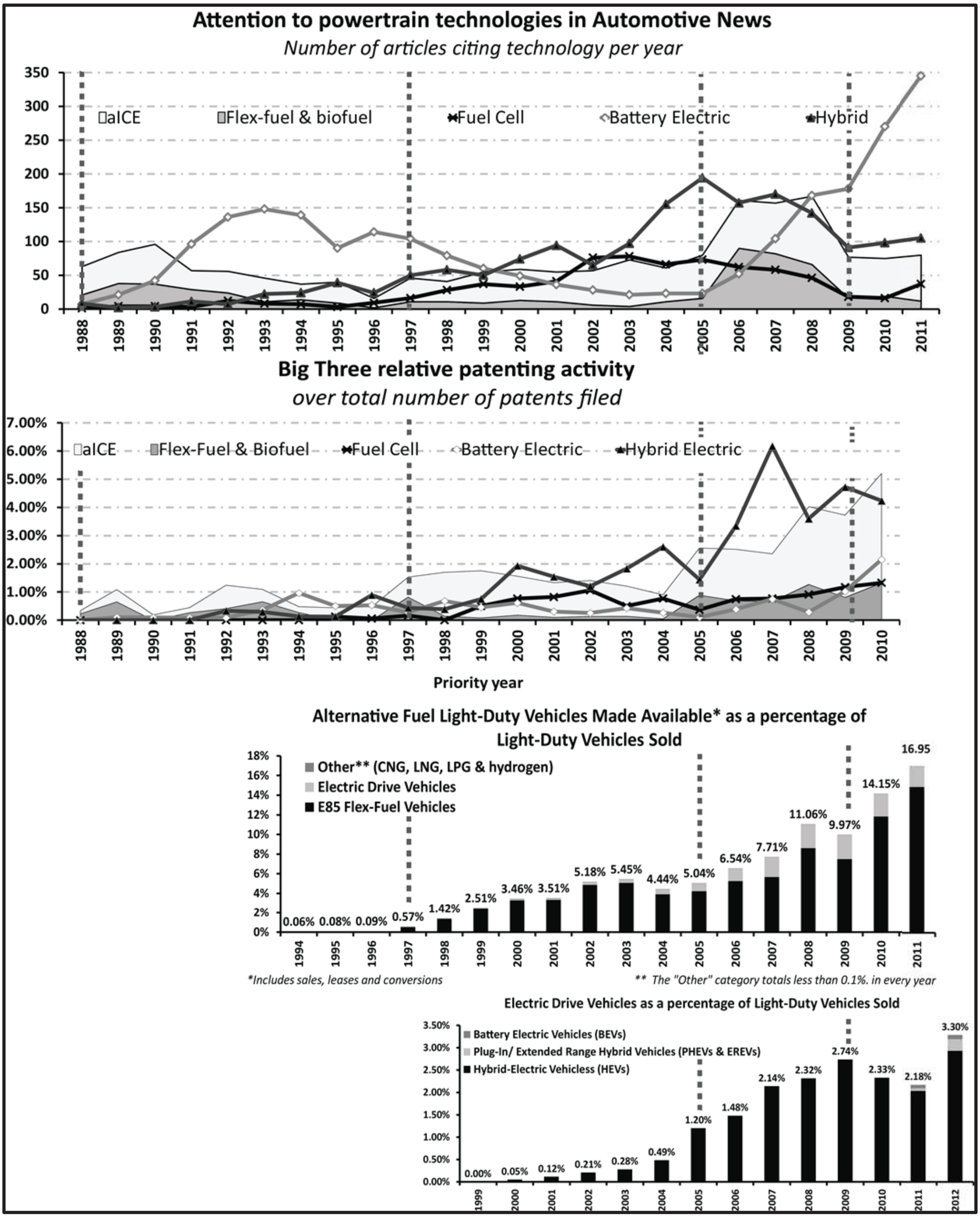


Figure 4 (a-d, top-down): Visual representation of proxy variables defined in section 3

To determine periods and break points (already represented above with vertical dotted lines), we used the results of QLR-tests for structural breaks, which are presented in Table 3. In Table 3 we have linked these break points to certain key events: a) the first break in public and congressional attention link with the 1988 Senate Hearings on global warming, b) public attention, Congress and Automotive News have all breaks associated with Kyoto, c) all series have a break in the mid-2000s, when climate change became a highly-salient issue, d) patenting and sales timeseries also have breaks associated with intra-industry events (e.g. GM's development of the EV *Impact* in early 1990s, the establishment of the battery development partnership USABC, Toyota's launching of the *Prius* and the consolidation of the HEV market).

	Breaks	Key episodes
Public attention to climate change	1986-1988* 1996+ 2005-2007*	1988: New York Times announces "Global Warming has begun" 1997: Kyoto Protocol 2005: Hollywood's *Day after tomorrow* 2007: Nobel Peace Prize to IPCC and Al Gore
Congressional attention to climate change	1984-1989* 1992-1997* 2006-2007*	1988: Senate Hearings on Global Warming 1997: Debate on Kyoto Protocol 2005: Energy Security Act
Executive attention to climate change	2004-2007*	2005: Second Bush (Jr.) administration 2007: Supreme Court's decision on EPA responsibility to regulate GHG emissions from cars
Automotive News attention to climate change	1995-1998* 2007*	Before-1997: industry denies climate change After-1997: industry begins to acknowledge climate change
Big Three AFV patents	1986-1988* 1990-1991* 2005-2006*	Late-1980s: GM develops EV model *Impact* 1991: *United States Advanced Battery Consortium* (USABC) formed by Big Three with Federal funds Mid-2000s: multiple technology hype cycles, Big Three catching up with HEV technology
Electric Drive market share	2000* 2003-2005*	2000: Toyota starts selling Prius (HEV) in U.S. Mid-2000s: consolidation of HEV market niche
HEV market share	2000* 2003-2007*	2000: Toyota starts selling Prius (HEV) in U.S. Mid-2000s: consolidation of HEV market niche

Table 3: Results of QLR tests for structural breaks and key episodes in the climate change issue lifecycle (Obs: *Significant at 1% level; +Insignificant local peak of QLR statistic)

Based on this analysis and a visual examination of charts in Figures 3 (charts a-d) and 4 (charts a-d) we distinguish five periods: 1979-1988 (when climate change had low salience), 1988-1997 (moderate public and political attention, and some patenting activity), 1997-2005 (gradual rise in public attention, political attention, and patenting: 'gearing up')), 2005-2009 (rapidly increasing public and political attention, accelerated patenting and HEV sales), and 2009-2012 (declining public and political attention because of the financial crisis, stagnating HEV-sales, high executive activities, and increasing patenting).

Figure 4a and 4b confirm the occurrence of various technology hype-cycles, although these are not as clean as represented in Figure 1. We distinguish five overlapping technology attention-cycles ('hypes'): 1st BEV hype (1988-early-2000s); HEV hype (2001-2009); FCV hype (1995-2009); biofuel hype (2006-2009) and new BEV hype (2005 onwards). The hype-cycles ('ups and downs') come out stronger in the Automotive News attention graph (Figure 4a) than in the patent graph (Figure 4b). This suggests that technological development may continue after attention bubbles have burst. Throughout the whole period, there is steady rise in patenting of all alternative technologies (Figure 3d), which indicates increasing industry attention to climate change. The qualitative case study will further analyse the drivers of various hype-cycles and their influences. Based on these Figures we advance four further observations.

- Industry attention and technology strategy towards flex-fuel vehicles and biofuels increased substantially by 2005 (Figure 4a and 4b). Patenting activity, however, increased relatively less than industry attention, which suggests that biofuels and flex-fuels were incremental innovations (requiring some tinkering with ICE, but no substantial redesign). The relatively low degree of biofuel patenting is even more striking if we consider the fact that biofuels/flex-fuels have reached some degree of market penetration (Figure 4c).
- Incremental improvements with a-ICE have been pursued throughout the entire period, but accelerated in the early 2005, indicating a ‘sailing ship’ effect, whereby threats from radical technologies stimulate old technology improvements.
- By 2010, there is substantial patenting activity for all technical options, which suggests that firms remain uncertain about which powertrain option will prevail, and therefore adopt a hedging strategy.
- Despite the attention and patenting in electric drive vehicles, Figures 4c and 4d show that actual market diffusion is dominated by biofuel and flex-fuel vehicles (FFV). In the later periods, electric drive vehicles only constitute a few percent of the total market, which may make automakers reluctant to abandon ICE vehicles. Furthermore, automakers prefer biofuels and FFV because these help them gain fuel efficiency credits and because these incremental innovations protect ICE-competencies.

The next section will further analyse casual connections and dynamic relationships.

5. Qualitative case study of climate change and the US car industry

We now turn to the qualitative case study of the different periods. Based on the initial quantitative analysis, we divide the case into five periods: 1979-1988, 1988-1997, 1997-2005, 2005-2009, and 2009-2018. Using the DILC-model as an ideal-type, we describe for each period: 1) problem-related pressures (from science, social movements, public opinion, policymakers), 2) response strategies from the car industry, 3) a discussion of the (mis)match with the conceptual phase-model.

5.1. Problem emergence, sense-making and industry indifference (1979-1988)

5.1.1. Pressures around issue

<u>Science, social movements, public attention.</u> In the 1970s, climate change emerged as a permanent research topic at scientific meetings and conferences, where possible causes, effects and uncertainties were discussed (Corfee-Morlot et al., 2007). The environmental movement began calling for measures

to tackle global warming. Public attention remained low (Figure 3a) because environmental news was dominated by other issues such as nuclear energy, acid rain and the ozone hole (Dunlap, 1992). Policy-makers. American political activity was symbolic, leading to a few Senate hearings and research funding decisions (Rothenberg and Levy, 2012). Senator Al Gore and others wrote a public letter (1986) declaring to be ‘deeply disturbed’ about climate change and calling for policy action (Yergin, 2011).

While climate change received little attention, policymakers were very concerned about energy security because of the first (1973) and second (1979) oil crisis. In 1974, they therefore enacted fuel economy regulations. The CAFE (Corporate Average Fuel Efficiency) standards started at 18MPG for 1978 models and would increase to 27.5MPG in 1985 (Figure 5). Because automakers had just opened up the light-truck market, they found it hard to comply (Doyle, 2000), leading the NHTSA (National Highway and Traffic Safety Administration) to relax the standards to 26MPG for 1986-1988 models, and 26.5MPG for 1989 models, with the 27.5MPG requirement postponed to 1990.

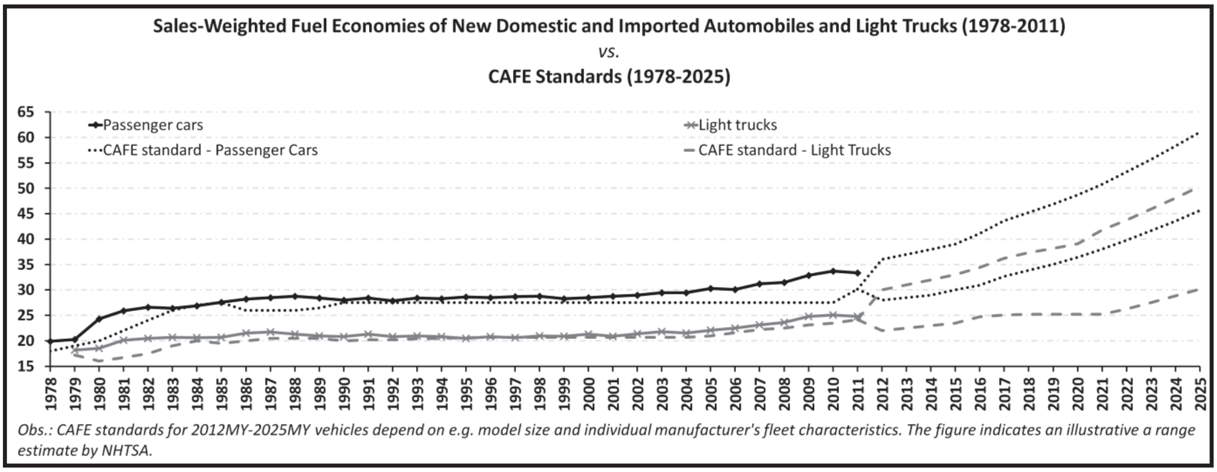


Figure 5: CAFE standards and fuel economy of new cars (Source: Author’s construction based on data from NHTSA (2011) and USEPA and NHTSA (2011))

5.1.2. Car industry issue responses

The car industry was unconcerned with climate change (Rothenberg and Levy, 2012). They were more interested in the opening up of a new market segment, starting with Chrysler’s *Minivan* (1983), and morphing into Sports Utility Vehicles. This market segment, which commanded high profit-margins (Doyle, 2000), was purposively designated as ‘light-trucks’, because this category was subject to more lenient fuel economy standards (Luger, 2000). This new market segment would dominate the American market in future decades (Figure 6).

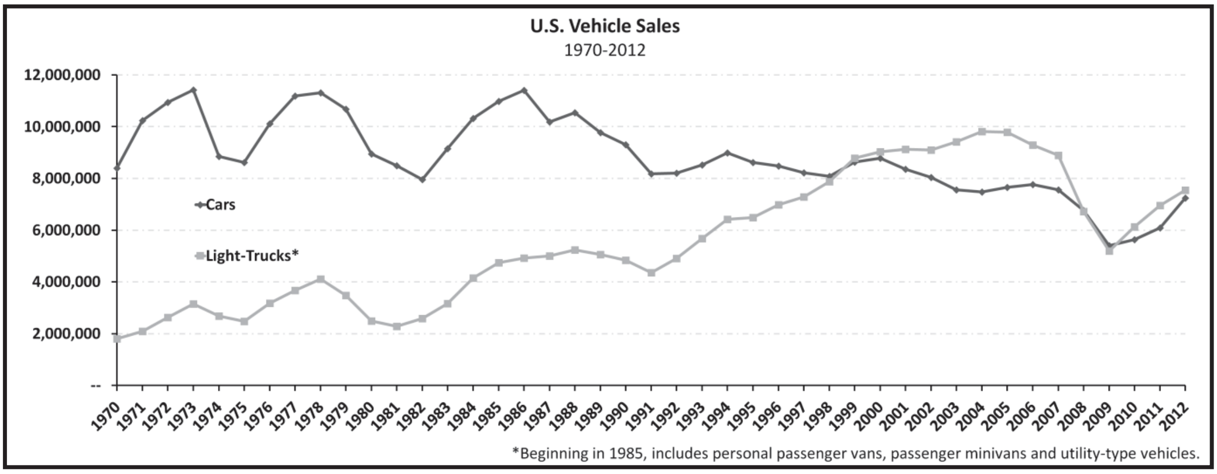


Figure 6: Sales of (light-duty) cars and light-trucks (Based on data from Ward's Auto (http://www.wardsauto.com/data-center))

5.1.3 Pattern-matching

This period fits well with DILC's phase 1: (a) scientists and environmentalists engage in sense-making and draw attention to the problem, (b) firms remain unconcerned. A minor deviation from the conceptual phase 1 is that politicians engaged in early symbolic action.

5.2. Rising public concerns and the creation of a closed industry-front (1988-1997)

5.2.1. Pressures around issue

Science, social movements, public attention. Public attention increased in the late-1980s and early 1990s (Figure 3a) because of hot summers (record-high temperatures, droughts), the 1988 Senate Hearing on global warming (see below), and framing struggles between scientists/environmentalists and climate-sceptics supported by industry (Doyle, 2000; Luger, 2000). The newly created (1988) *Intergovernmental Panel on Climate Change* (IPCC) also stimulated public attention with comprehensive assessment reports (in 1990 and 1996), which reviewed and integrated scientific findings (Corfee-Morlot et al., 2007).

Policy-makers. Political action occurred at multiple levels. The first IPCC report (1990) provided the basis for international negotiations, which resulted in heads of state signing the *United Nations Framework Convention on Climate Change* (UNFCCC) at the 1992 *Rio Earth Summit*. Although Rio 1992 established the goal of stabilizing greenhouse gas (GHG) concentrations, the Framework was a voluntary, non-binding agreement (Kolk and Levy, 2001). In 1995 (Berlin), signatory parties agreed that targets would be formulated for industrialized nations but not for developing countries. In 1996 (Geneva), parties accepted the findings from the second IPCC assessment report, and called for legally-binding targets and timeframes (Corfee-Morlot et al., 2007).

At the U.S. Federal level, the 1988 Senate hearings marked the emergence of climate change as a political issue (in policy sub-systems and (briefly) at the macro-political level). The testimony of

NASA climate scientist, James Hansen, was widely reported in the mass media[8], and politicians began jockeying for the fatherhood of a 'global warming act', proposing various bills that addressed global warming via fuel economy legislation or clean air policy (Doyle, 2000).[9] These bills failed to pass because of strong corporate lobbying or threats that the President would use his veto (Doyle, 2000). Instead of targets and regulations, Bush (senior) preferred a voluntary approach through public-private partnerships (PPP) aimed at developing advanced technologies and the promotion of alternative (mainly ethanol/methanol) fuels (Duffield et al., 2008; Yergin, 2011). The newly elected (1993) president Clinton also preferred collaboration over legislation, and established the *Partnership for a New Generation of Vehicles*. In return for industry participation, he offered a moratorium on mandated fuel economy increases (Luger, 2000).

At the U.S. state level, California's 'Zero-Emission Vehicle' (ZEV) mandate (1990) was a radical legislation that required the seven biggest automakers to sell a fleet mix that included different categories of vehicles according to increasingly stringent emission levels (Table 4) and setting a tough fine ($5,000) per non-compliant vehicle (Kemp, 2005).[10] The plan was in effect a sales mandate, because "battery-powered electric vehicles [were] the only zero emission automotive technology on the horizon" (Doyle, 2000:274). By 1994, other states were considering to adopt the Californian ZEV mandate, which led the Big Three (GM, Ford, Chrysler) to start an intense lobbying campaign (Doyle, 2000). The ZEV-regulation also established a biannual review process, which offered carmakers an opportunity to shape the policy process. While the original regulation survived the first two reviews, CARB (California Air Resources Board) dropped the 1998-2002 requirements in 1996 under great pressure from automakers (Kemp, 2005).

Model Year	Conventional vehicles	Transitional Low Emission Vehicles (TLEV)	Low Emission Vehicles (LEV)	Ultra-Low Emissions Vehicle (ULEV)	Zero-Emission Vehicles (ZEV)
1994	90%	10%	-	-	-
1995	85%	15%	-	-	-
1996	80%	20%	-	-	-
1667	73%	-	25%	2%	-
1998-2000	48%	-	48%	2%	2%
2001-2002	-	-	90%	5%	5%
2003	-	-	75%	15%	10%

Table 4: CARB original sales requirements under the LEV/ZEV mandate (Kemp, 2005:175)

[8] The New York Times (24/6/1988) published an article with the headline 'Global Warming has begun, expert tells senate'.
[9] Examples are the *Global Warming Prevention Act* (which included a fuel efficiency mandate of 45 mpg for cars and 35 mpg for trucks by 2004); the *National Energy Policy Act*; the *World Environment Act* (sponsored by Senator Al Gore); the *Global Environmental Protection Act* (calling for a 50% reduction in automotive carbon emissions, equivalent to a fuel economy standard of 55 mpg).
[10] The ZEV-mandate's initial rationale was addressing local air pollution. But it subsequently became part of California's strategy to control GHG emissions (CARB, 2012).

5.2.2. Car industry issue responses

Social-cultural strategies. In 1989, the Big Three, the American Automobile Manufacturers Association (AAMA), and forty other American companies formed the *Global Climate Coalition* (GCC), which created a 'closed industry front' that attacked global warming science and accused the IPCC of downplaying uncertainties (Doyle, 2000). American automakers also set up 'astroturf' organizations that created pressures on politicians. The 'grassroots' Coalition for Vehicle Choice (CVC), for instance, initiated letter-writing campaigns to politicians and promoted the view that stricter CAFE standards[11] would limit vehicle choice and 'outlaw' SUVs and pick-ups (Luger, 2000).

Political strategies. Automakers attacked the Californian ZEV mandate with the AAMA officially establishing the strategic goal of "creating a climate in which the [California EV] mandate [...] can be repealed" (cited in Doyle, 2000:294). For the ZEV-mandate's third review (1996) the Big Three aligned their position, complaining about the state of battery development, low consumer demand, and lack of infrastructure (Johnson, 1999): "the automakers joined together to insure that none of them separately would go out ahead of the others – although GM clearly had the technological lead" (Doyle, 2000:322). An independent Battery Technology Advisory Panel also concluded that battery costs would represent a barrier to EV diffusion by 1998 (Doyle, 2000; Kemp, 2005). In 1996, CARB decided to drop the 1998-2002 sales requirements.

American automakers also opposed Federal proposals to increase fuel economy standards. Financial contributions incentivized politicians to vote against legislation, resulting in "a strong correlation between the amount of money received from the auto industry and [Senators'] votes" on CAFE proposals (Luger, 2000:168).

Innovation strategies. Environmental technology strategies of American automakers mostly focused on incremental innovations such as advanced-Internal Combustion Engine (aICE) technologies (Figure 4b), which included improved fuel injection systems and lean-burn catalysts (Mondt, 2000). Another strategy to defend existing ICE technology was the development of ethanol-fuelled or flex-fuel vehicles (FFV), which were capable of running on methanol/ethanol or gasoline or a mixture of both (e.g. E85, an 85% ethanol-gas mixture). Automakers also focused on FFVs because the 1988 *Alternative Motor Fuels Act* (AMFA) assigned CAFE credits to their production (Duffield et al., 2008). By 1997 almost 85,000 E85 Flex-Fuel Vehicles were sold, leased or converted (Figure 4c).

Carmakers (except GM) gave relatively little innovative attention to alternative powertrain technologies (van den Hoed, 2005). In the late 1980s, General Motors dedicated some resources to a radical innovation (BEV) for reputational reasons. The *Impact*-prototype was meant to demonstrate that GM was not a stale, boring company, but still mustered innovative capabilities (Johnson, 1999). The *Impact* 'show-car' generated positive publicity at the Los Angeles Motor Show (1990), leading GM's chairman to announce that GM would market the car (Doyle, 2000). CARB interpreted this

[11] Although CAFE standards were originally created to address energy security, they were increasingly called upon by environmentalists and policy-makers as a means to address CO_2 emissions.

announcement as an indication that BEVs were sufficiently developed, and issued the ZEV mandate a few months later (Kemp, 2005). Subsequently, GM created a 400-person, $300-million BEV programme (Doyle, 2000) to produce 25,000 vehicles per year by 2000 (Kemp, 2005).

To contain the possibility of an innovation race, the Big Three formed another closed industry-front (1991) so that all companies would move together technologically. The *U.S. Advanced Battery Consortium* (USABC) was a public-private partnership launched by President Bush (senior) and the Big Three (Doyle, 2000). Although most of the funds came from the Department of Energy (DoE), the Big Three ran the program and decided which battery developers and projects received grants (Doyle, 2000). The USABC fulfilled several roles for American automakers (Doyle, 2000; Luger, 2000): a) improving their public reputation, b) controlling technical development, c) managing technological expectations through the establishment of (unrealistic) mid-term goals (such as a minimum driving range of 150-miles) “that enabled an indefinite postponement of progress” (Doyle, 2000:308); and d) controlling the release of technical information to policymakers to prevent that standards would be ratcheted up. According to a former GM employee, “the automakers formed USABC to hinder rather than enhance product development by controlling research and development efforts” (cited in Doyle, 2000:309).

In 1992, GM down-scaled its BEV project to a $32-million demonstration programme of 30-50 cars/year, with a third of initial personnel (Doyle, 2000; Kemp, 2005). GM decided to lease its electric car for $33,995, about half of real costs of $78,000 (MacCormack, 2005). By 1996-7, GM had leased about 760 units (MacCormack, 2005), which was far below initial expectations. Critics accused GM of deliberately under-promoting electric cars (Sperling and Gordon, 2009).

In 1993 American automakers also joined the *Partnership for a New Generation of Vehicles* (PNGV). This $300-million joint-venture with Federal research laboratories aimed at developing a ‘production prototype’ by 2003, capable of reaching a fuel economy of 80MPG, without sacrificing size, performance or safety (Doyle, 2000). PNGV served similar purposes as USBAC: directing technical developments, controlling technological expectations and playing on information asymmetries. In exchange for their participation the Big Three also secured a moratorium on Federal CAFE increases (Doyle, 2000). The Big Three also used the PNGV to pre-empt regulatory action, claiming that self-regulation and PPP was more effective than ‘command-and-control’ regulations. Although PNGV developed some new technologies (e.g. lightweight materials, lithium-ion battery cell, fuel-flexible processors for a fuel cell), the Big Three directed most research efforts towards incremental technologies for advanced diesel engines (e.g. lean-burn NO_x catalysts, diesel direct fuel injection systems) and (diesel) hybrid powertrains (Mondt, 2000).

Foreign automakers. In response to the ZEV mandate and PNGV, Toyota decided to develop a car with 100% fuel economy improvement, which in 1997 resulted in the Toyota *Prius* hybrid car. In 1997, Honda also demonstrated their *Insight* hybrid car (Doyle, 2000). HEVs were initially derided by the industry, because twin-powertrains substantively increased costs. GM perceived HEVs as ‘interim’ technology, and decided instead to focus on fuel cells, which would "make hybrids obsolete" (MacCormack, 2005:15). DaimlerBenz pioneered FCVs and unveiled a cumbersome prototype, the NECAR I [New Electric Car], in 1994. The smaller NECAR II (1996) triggered more enthusiasm (Budde et al., 2012) and put fuel cells on the map of zero-emission technologies.

Market positioning strategies. Climate change hardly affected American automakers' market positioning strategies, which was firmly oriented towards selling profitable light-trucks. Car and truck sales fell in the early 1990s (Figure 6), because of the economic recession, causing major financial problems (Figure 7). GM suffered major losses, because of additional expenditures for pension fund commitments (Ingrassia, 2010). The financial situation improved after 1993 (Figure 7), because of the booming the light-truck market (Figure 6).

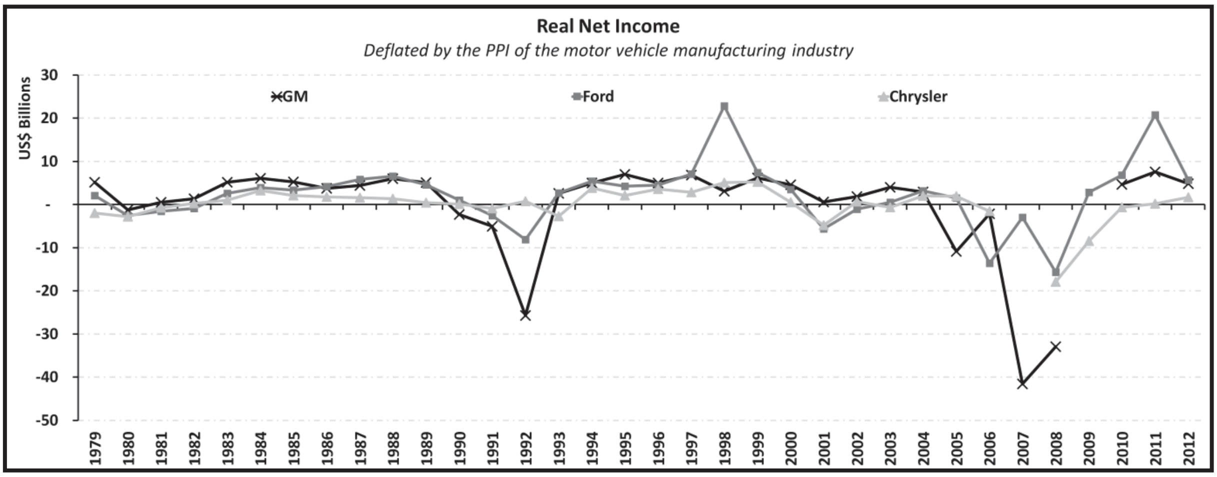


Figure 7: Real net income (2012 dollars, deflated by the PPI) of the Big Three (Geels and Penna, 2013 and companies' financial statements) (Obs.: From 1998-2006, Chrysler's figures correspond to the operating profit (loss) of the Chrysler Group of DaimlerChrysler)

5.2.3. Pattern-matching

This second period displayed important dynamics of DILC's phase 2: (a) increase in public attention; (b) symbolic political action at the Federal and global level, accompanied by the early build-up of a policy sub-system; (c) creation of a closed industry-front. But the period also had some deviations from the conceptual model: (1) at the state level, California's Zero Emissions Vehicle (ZEV) mandate formed a strong piece of regulation (which the model predicts in phase 4); (2) early engagement of macro-politicians (Presidents Bush Senior and Clinton), which the model posits to phase 4, and (3) an incumbent firm (GM) introduced a radical innovation (BEV), which the model predicts in phase 4. We argue, however, that this period is best characterized as phase 2, because of the following qualifications of the second and third deviation: the partnerships established at the macro-political level (USABC and PNGV) served to *reinforce* the closed industry front; GM promoted BEVs for reputational reasons, not in reaction to the climate change concerns or regulation.

5.3. Political stalemate and defensive hedging (1997-2005)

5.3.1. Pressures around issue

Social movements, public attention. Public attention increased in 1997 (Figure 3a) because of the Kyoto treaty. Progressive businesses such as the *Pew Center on Global Climate Change* began to endorse the climate change issue (Rothenberg and Levy, 2012), advancing a 'win-win' discourse, which argued that proactive climate change strategies could open up new business opportunities. In 1999, environmentalists filed a petition to the EPA requesting it to undertake its 'mandatory duty' of regulating motor vehicle GHG emissions.

Policy-makers. At the global level, the Kyoto Protocol (1997), in which many countries pledged to reduce GHG emissions by an average of 5% below 1990 levels by 2012, was a significant political step (Doyle, 2000). Although the US played a key role in the negotiations, Clinton/Gore never submitted the treaty for Senate ratification, because they anticipated rejection (Doyle, 2000). In Europe automakers signed a 'voluntary' agreement (in 1998) with the European Commission to reduce average new car emissions to 140 grams of CO_2 per kilometre (39MPG) by 2008-9.

In 2001, the newly elected President Bush (junior) rejected the Kyoto Protocol for being 'unfair and ineffective', creating regulatory stalemate at the Federal level. Some US congressmen proposed legislation to address GHG emissions. Senators McCain and Lieberman, for instance, proposed a cap-and-trade system in 2003, but the bill was never voted on. Other bills also faced strong opposition (Yergin, 2011). In 2003, EPA denied the petition filed by environmental groups, arguing that EPA did not have authority under the Clean Air Act to regulate GHGs (Meltz, 2008). The State of Massachusetts (with eleven other states, three cities, two U.S. territories, and several environmental NGOs) appealed, but this was rejected by Appeals Court in 2005.

Although the government did not regulate, it stimulated technological development, particularly of fuel cells, with the 2003 *FreedomCAR and Fuel Partnership* and the 2004 *Hydrogen Fuel Initiative*, a $1.2 billion research-funding project that resulted in DoE's *Hydrogen Program*. These programs, which aimed at both energy security and climate change, increased available funding (Figure 8) and contributed to fuel-cell enthusiasm (Bakker *et al*., 2012).

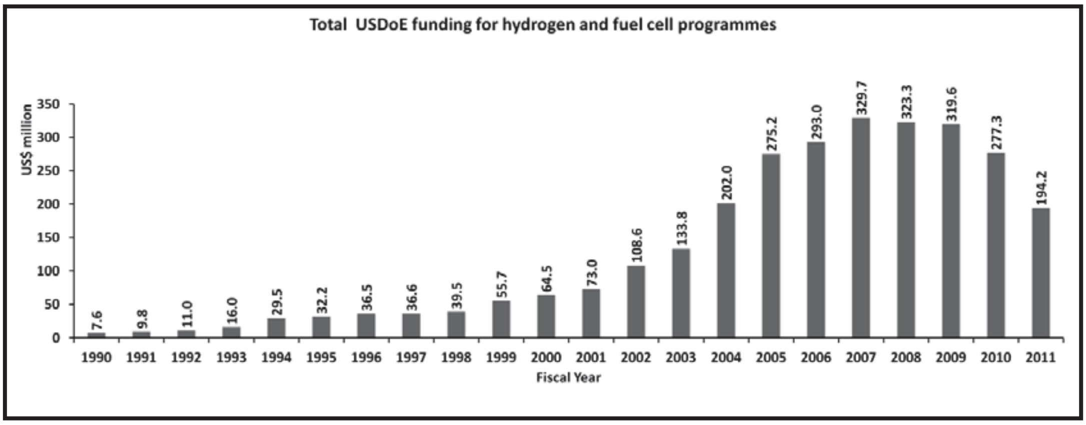


Figure 8: Department of Energy (DoE) funding for fuel cell and hydrogen programmes (Based on data from Peterson and Farmer, 2012)

Climate change policy also experienced difficulties in California. Because of limited market demand for low-emission vehicles, CARB's fourth ZEV mandate review (1998) gave automakers more flexibility, e.g. postponing some requirements, establishing a credit system (Kemp, 2005). In 2001, CARB recognized barriers due to cost, lead-time, and technical challenges, and further amended the mandate, requiring only 2%-sales of 'pure-ZEVs'(BEVs and fuel cell vehicles) by 2003 (Kemp, 2005). CARB also gave automakers the option of meeting the remaining 8%-requirement with 2%-sales of 'Advanced Technology Partial Zero Emission Vehicles' (AT PZEVs), such as HEVs, plus 6% of Partial Zero Emission Vehicles (PZEVs), such as natural gas and 'super-clean' gasoline vehicles. GM (and other companies) contested the 2001 amendments in court (see below), which in 2002 resulted in a court decision which prohibited CARB to enforce the programme, causing gridlock for the ZEV mandate. To overcome the political gridlock CARB's 2003 amendments removed all references to fuel economy, delayed the ZEV requirements to 2005, and included two compliance paths, one similar to the 2001 amendments (2% pure ZEVs + 2% AT-PZEVs + 6% PZEVs), the other setting up a mechanism to promote the diffusion of fuel cell vehicles: automakers would be exempted from the 2% pure ZEV requirement if they would increase sales of FCVs from 250 by 2008 to 50,000 by 2017.

Another development was that the State of California adopted the *Pavley Act* in 2002, which instructed CARB to regulate GHG emissions from motor vehicles (Sperling and Gordon, 2009). In 2004 CARB issued new rules requiring 30% reductions in new car GHG emissions by 2016 (Lutsey, 2012).

5.3.2. Car industry issue responses

<u>Socio-cultural strategies.</u> American automakers initially endorsed the GCC approach of contesting climate science, influencing public opinion and lobbying Washington politicians (Doyle, 2000). But in the late 1990s, they changed their position because of several reasons: (a) fear that climate denial campaigns would damage their reputation in the context of increasing public concerns (Doyle, 2000); (b) foreign automakers benefitted from a 'halo effect' on their reputations for selling 'greener' cars (Abeles, 2004); and (c) they faced credibility pressures from constructive business coalitions (*Pew Center*) and the 'win-win' business discourse. Ford abandoned the GCC in 1999, acknowledging the climate change problem and calling upon the auto industry to show leadership. GM and Chrysler followed in 2000. This was a major change in position, weakening part of the industry's closed industry front (Rothenberg and Levy, 2012).

<u>Political strategies.</u> Although American automakers acknowledged the climate change problem, they politically opposed federal fuel economy standard. Also in California they testified against the ZEV mandate in CARB's 2000 hearings, arguing that consumers were not willing to pay for BEVs (Sperling and Gordon, 2009). Automakers argued in favour of the 'more promising' fuel cell

technologies, and cited their voluntary research initiatives to argue that regulation was not needed (Doyle, 2000). Although CARB relaxed ZEV requirements in 2001, the industry opposed *any* kind of ZEV mandate. GM therefore led a lawsuit against CARB, arguing that the ZEV-mandate was pre-empted by Federal CAFE standards (Metz, 2008). The underlying motivation was that carmakers preferred to discuss climate change regulations at the Federal level, where they had a powerful lobbying force and support of many congressmen (Sperling and Gordon, 2009).

Automakers also opposed the Pavley Act (2002), suing the state of California questioning (a) whether GHG was a pollutant under the CAA (which would allow California to set stricter emission standards) and (b) whether setting GHG emission standards was the same as setting CAFE standards (which was a Federal and not a state-level duty) (Meltz, 2008). The legal processes dragged on, gaining automakers several years of delay. Additionally, Detroit automakers secured 'political favours' from the Bush administration such as extended CAFE credits for vehicles that can burn E85, even if those vehicles never use anything but gasoline (Sperling and Gordon, 2009).

<u>Innovation strategies.</u> On technical dimensions, American automakers hedged. On the one hand, their main orientation remained the incremental improvement of ICEs and the marketing of flex-fuel vehicles. The combined share of a-ICE and FFV/biofuel patents in the Big Three annual portfolio trebled from 0.5% in 1996 to an average of 1.5% in 1997-2005 (Figure 4b). On the other hand, they accelerated investments in alternative powertrain technologies, but without strong intention of mass-marketing (Doyle, 2000). Longer-term technology strategies shifted from battery-electric vehicles to fuel cell vehicles (van den Hoed, 2007), causing a change in industry attention (Figure 4a) and industry patenting (Figure 4b). American carmakers also established the *California Fuel Cell Partnership* (1999), which was a cooperative joint-venture between CARB, incumbent automakers and oil companies (Sperling and Gordon, 2009). From 2000 to 2007, fuel cell enthusiasm resulted in increasing numbers of hydrogen/fuel cell prototypes (Figure 9) and optimistic promises about technological developments and commercialization). But gradually these promises were projected further (about 10-15 years) into the future, causing inflation of the hydrogen hype after 2006/7 (Bakker, 2010a).

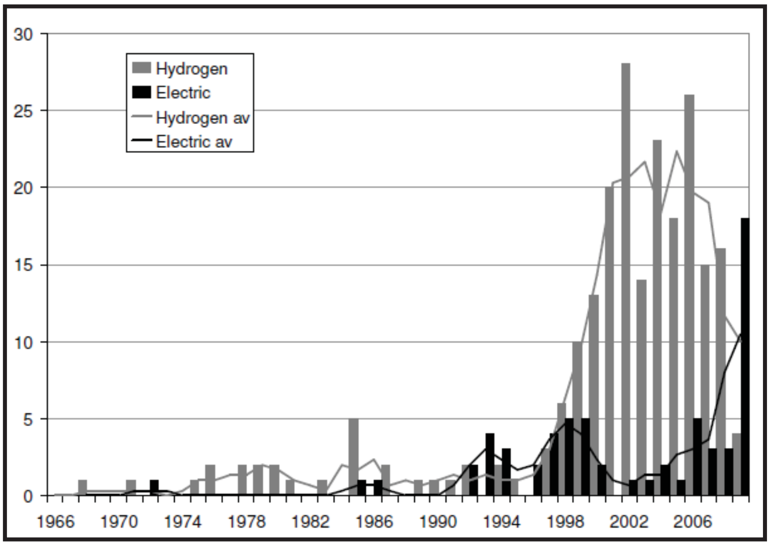
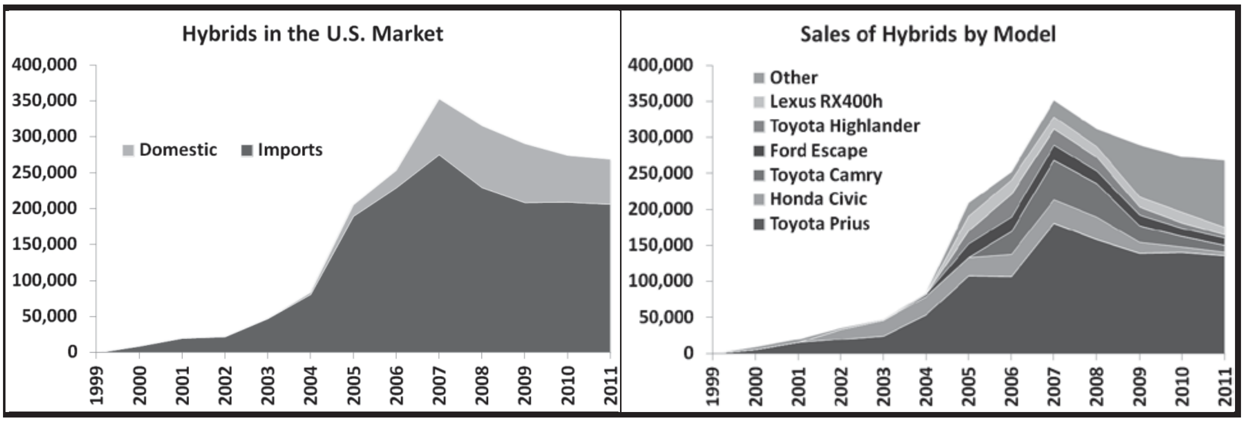


Figure 9: Absolute numbers (worldwide) of hydrogen and battery-electric prototype models per year (1966-2009), with three-year moving average lines added (Bakker and van Lente, 2009)

The PNGV made limited contributions to new technology development, with the industry's trade journal *Automotive News* recognizing that the Partnership "produced few tangible results" (Stoffer, 2002). Critics claimed that the benefits of PNGV were more political than technological.

Foreign automakers. PNGV had an unintended consequence, because foreign automakers perceived it as a serious technology development program (Sperling and Gordon, 2009). In response, Toyota and Honda pushed the commercialization of HEVs, while Daimler-Benz (DaimlerChrysler from mid-1998) led fuel cell developments. The two-seater Honda *Insight* (introduced in the US market in 1999) and Toyota *Prius* (introduced in 2000) boosted the environmental and technological reputation of Japanese companies (Abeles, 2004). The Prius, in particular, became a personal statement of environmental consciousness (Abeles, 2004). Hybrid sales accelerated after 2004 (Figure 10, 11).



Figures 10 and 11: Sales of HEVs in the US market (Source: Author's elaboration based on data from RITA/BTS, 2012 and www.afdc.energy.gov/afdc/data/, respectively)

Daimler became a leader in FCVs (Hekkert and van den Hoed, 2006). In 1999, DaimlerChrysler managed to fit a fuel-cell system (costing $35,000 apiece) on a 5-seat passenger car (NECAR 4). This led its Chairman to declare that "the race to develop the fuel cell car is over [...] Now we begin the race to lower the cost to the level of today's internal combustion engine. We'll do it by 2004" (quoted in The Economist, 1999: 88). In 2000, DaimlerChrysler announced investments of $1.4 billion to bring FCVs to market (van den Hoed, 2005). The goal was to sell 40,000 fuel cell cars by 2004, ramping up production to 100,000 by 2006 (Sperling and Gordon, 2009). These optimistic announcements triggered a 'fuel cell hype' and innovation race, with most car companies investing in FCV-research (Bakker, 2010a) (see also Figures 4a,b). FCVs seemed promising because of energy efficiency, quietness, quick refuelling, and zero emissions, without compromising on performance. But high relative costs and the lack of a hydrogen infrastructure formed problems for market uptake (Sperling and Gordon, 2009).

Market positioning strategies. The Big Three's positioning strategy continued to focus on flex-fuel vehicles, which helped them obtain CAFE credits. By 2005, flex-fuel vehicles (4.22%) made up the bulk of total AFV sales (5.04% of total U.S. light-duty sales) (Figure 4c). In 2002, when it leased only 457 units of the second generation EV1, GM decided to discontinue production and lease contracts (Sperling and Gordon, 2009). This decision aligned with GM's political position (opposing ZEV mandate) and shifting strategy towards fuel cells. The decision had negative reputational effects, because critics claimed that it was a political move to obstruct the ZEV programme (e.g. the documentary *Who killed the electric car?*, launched in 2006 by a former EV1-leasee).

General market conditions for American automakers continued to decline (Figure 12): as foreign firms (especially Japanese automakers) gained market share, American automakers became increasingly reliant on the light-truck segment. World-wide pressures accelerated consolidation in the global automotive industry, with Chrysler merging with Daimler (1998), Hyundai taking over Kia (1998); Renault and Nissan establishing the Renault-Nissan Alliance (1999); Ford acquiring Volvo (1999); GM acquiring Saab (2000).

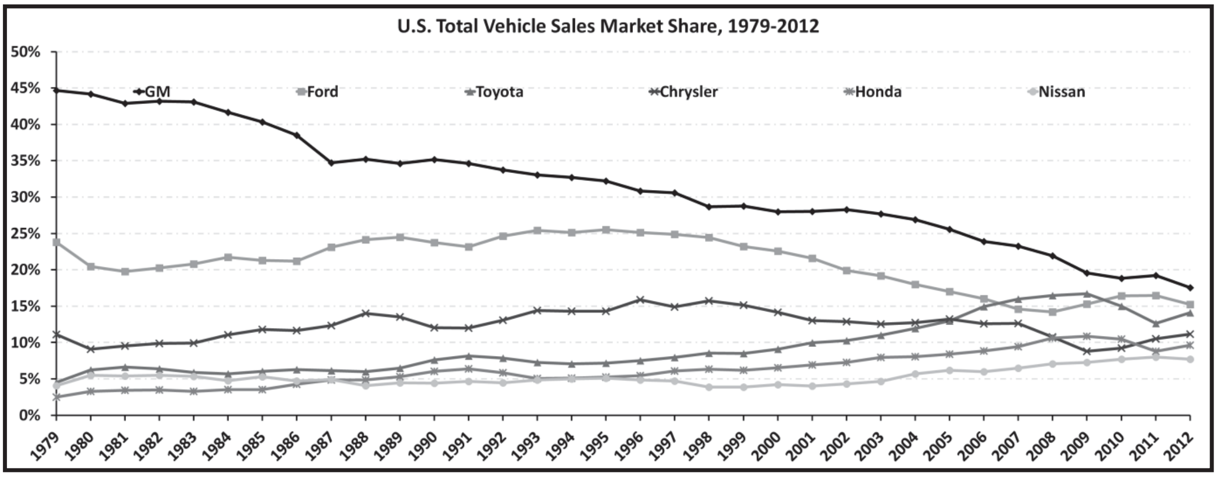


Figure 12: Market share of top-6 sellers in U.S. (as of 2012) (Based on data from Ward's Auto (http://www.wardsauto.com/data-center))(Chrysler's figures exclude Daimler's share)

5.3.3. Pattern-matching

This third period has a good match with phase 3 in the DILC-model, because: (a) public attention to climate change further increased, (b) specialist expertise was elaborated in policy sub-systems (CARB, PNGV, USABC), (c) automakers acknowledged the problem, but opposed it politically causing controversy and deadlock, (d) limited macro-political pressure because Congress and the Bush-administration opposed regulation, (e) automakers moved towards hedging strategies, maintaining their overall commitment to aICE and biofuels/FFV, but increasing R&D investments in more radical alternatives. The period also had a few deviations, because it included some elements from phase 4: (1) the political industry front weakened as firms abandoned the GCC, (2) foreign firms (Toyota, Daimler) aimed to secure first-mover advantages with radical innovations (HEV, FCV), which 'opened up' the industry front, and triggered innovation races.

5.4. Changing gear (2005-2009)

5.4.1. Pressures around issue

<u>Public attention.</u> Public attention greatly accelerated after 2005 reaching an unprecedented peak in 2007 (Figure 3a), because of several catalytic events: a) Hurricane Katrina (2005) became a powerful image of potential consequences of climate change; b) Tony Blair declared climate change a top priority at the 2005 G8 meeting; c) Al Gore's movie *An Inconvenient Truth* (2007) boosted climate change awareness; d) the IPCC's *Fourth Assessment Report* (2007) reported a scientific consensus about an 'unequivocal warming trend'; e) the IPCC and Al Gore were awarded the Nobel Peace Prize (2007). Increasing public attention created pressure on policymakers and industry.

<u>Policy-makers.</u> Oil prices, which had been rising steeply since 2003 (Figure 13), caused concerns for the re-elected (2004) Bush administration, resulting in the 2005 *Energy Act* and the *Energy Independence and Security Act* (2007). These acts signalled a shift in policy-orientation, because they were the first comprehensive energy policies in more than a decade. They also contributed to unlocking the federal regulatory stalemate. While these Acts were primarily motivated by oil prices and energy security concerns, they also stimulated low-carbon technologies in the transport domain. The 2005 Energy Act mandated a 100%-increase in the volume of ethanol mixed with gasoline between 2006-2012, and provided R&D subsidies for HEVs, FCV and advanced battery research. The 2007 Act mandated a further increase in biofuel production to 36 billion US gallons by 2022 (Sperling and Gordon, 2009), making biofuels into a crucial national strategy and stimulating the diffusion of flex-fuel vehicles (Figure 4c). The 2007 Act also raised CAFE standards to 35MPG by 2020, linking energy security and fuel efficiency to the climate change agenda.

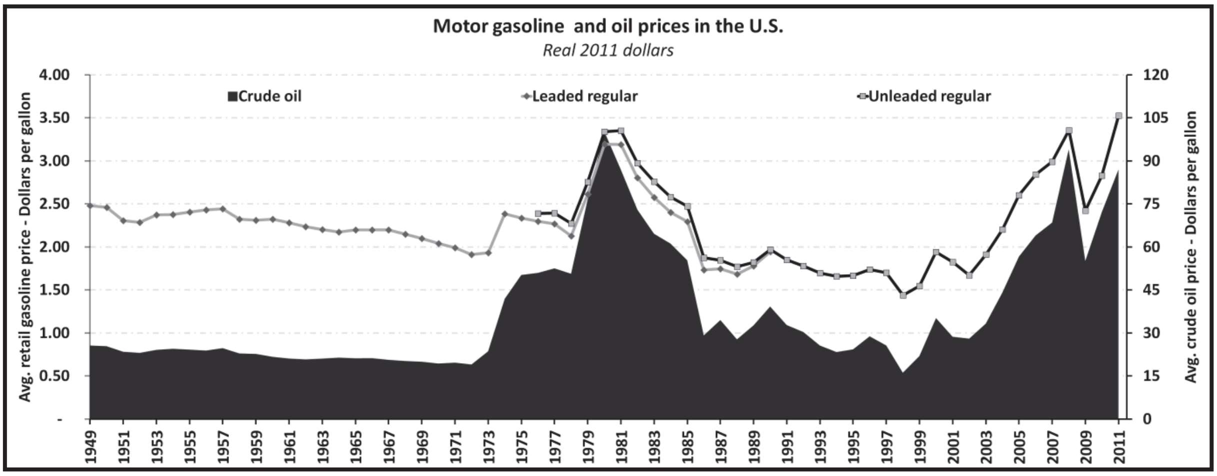


Figure 13: Motor gasoline and oil prices in the US in real 2011 dollars (Based on data from the US EIA (http://www.eia.gov/petroleum/data.cfm#prices), accessed on Oct. 23rd, 2012)

In Europe, frustration with automakers, who were on track to miss the voluntary 1998 agreement, led policymakers (in 2007) to issue mandatory car-emission standards for 2015 (130 gCO_2/km or 42MPG). Japan followed suit, setting its standard at 125 gCO_2/km (or 44MPG) for 2015.

Also in 2007, a judicial decision about the petition filed in 1999 broke the regulatory deadlock. In the 2007 case *Massachusetts v. EPA*, the Supreme Court ruled that (a) carbon dioxide and other GHGs are pollutants, and thus regulated under 1990 CAA; and (b) the CAA does not authorize EPA to make policy considerations (Meltz, 2008). This judicial order meant that existing fuel efficiency and environmental regulations could be extended to address climate change. The ruling also labelled GHGs as air pollutants, which gave CARB the *right* to legislate GHG emissions in California. But CARB did not yet gain the *means* to implement the legislation, because automakers successfully lobbied the Administration not to grant California the necessary waiver (Sperling and Gordon, 2009). The argument was that the 2007 Energy Act, which tightened fuel economy standards, pre-empted the need for California to have its own GHG standards (Sperling and Gordon, 2009).

5.4.2. Car industry issue responses

Socio-cultural strategies. In response to escalating public concerns, automakers acknowledged climate change in their annual reports and signalled their engagement with sustainable mobility. Marketing strategies also embraced sustainability messages.

Political strategies. In 2007, GM, Ford and Chrysler joined the U.S. Climate Action Partnership (USCAP), which promoted market-based approaches (e.g. cap-and-trade legislation) rather than regulation to achieve reductions in greenhouse gas emissions (Yergin, 2011). .

Innovation strategies. By 2006-2007 fuel cell enthusiasm began to diminish (see Figure 8 and 9) because of cost problems, technological barriers (e.g. hydrogen storage), and a lack of hydrogen fuelling stations. The fuel cell hype was superseded by new expectations about and HEVs, PHEVs, and BEVs (Figures 4a,b, 9). By 2005, sales of HEVs accelerated (Figures 10, 11), stimulating industry attention and patenting (Figures 4a,b). In response to Toyota's first-mover advantages, GM and Ford boosted their R&D activities, leading to changes in patenting portfolio (Figure 4b). Ford produced its first full-hybrid (Escape) in 2004 (using licensed hybrid technology from Toyota) and GM in 2007 (Sperling and Gordon, 2009).

Foreign automakers and new entrants. BEVs were revitalized by foreign automakers such as Renault-Nissan which in 2002 announced a breakthrough in lithium-ion battery technology that would extend the driving range (Yergin, 2011). Renault-Nissan promised to market BEVs in 2010. A new automaker, Tesla Motors, further reinforced attention, because the marketing of its *Tesla Roadster* (2006) in terms of style, verve, and performance gave BEVs a positive symbolic meaning (Yergin, 2011). The subsequent surge in interest in BEVs (Figure 4a) spurred other automakers to reconsider the technology.

Market positioning strategies. Economic positioning of American automakers continued to focus on biofuels and flex-fuel vehicles which sold in increasing numbers (Figure 4c).

The HEV market, which expanded rapidly after 2005 (Figure 10, 11), also attracted attention. Toyota's second-generation Prius, larger and more powerful but at similar cost ($20,000), led the way. By 2007, Prius was the 8th top selling car in the U.S (13 for all light-duty vehicles) (Sperling and Gordon, 2009). Other companies followed, leading to an innovation race and a rapid increase in the number of available models. Absolute HEV sales peaked in 2007 (Figures 10, 11), corresponding to about 2% of the U.S. light-duty vehicle market (Figure 4d).

General market conditions worsened, as rising oil prices depressed sales of light-trucks (Figure 13). To continue to sell SUVs, American carmakers offered a range of 'marketing gimmicks', such as zero interest loans, rebates and free options. They also aimed to cover automotive losses with profits from financial divisions, which diversified into mortgages, including sub-prime (Ingrassia, 2010). Declining light-truck sales and 'legacy' costs (pensions, health care) caused major losses for American automakers, peaking at US -$40.5 billion for GM in 2007 (Figure 7), when the subprime bubble burst. The outbreak of the 2008 financial crisis caused major financial troubles for the Big Three.

5.4.3. Pattern-matching

This fourth period as some elements from phase 4 in the DILC-model: (a) sharp increase in public attention, (b) engagement of macro-political actors (second Bush-administration, Supreme Court, (c) spillovers to the economic task environment through the emergence of markets for low-carbon technologies, (d) further opening up of the industry front and innovation races in FCV, HEV and biofuels/FFV. Because many of these developments point in the 'right' direction, we titled this period as 'changing gear'. But the period also has elements of phase 3, because some developments are not yet very strong: (1) regulatory pressure remains limited (because federal policies are not radical), (2) market niches remain small (2-3%), (3) continuing commitment of automakers to aICE and biofuels/FFV; (4) automakers also invest in more radical alternatives, but do not fully commit to any option for fear of making the wrong bet (which is reinforced by the experience of hype-cycles). This period is therefore best characterized as a 'phase 3½'.

5.5. The climate change issue at crossroads (2009-2018)

5.5.1. Pressures around issue

Public attention. After 2007 public attention to climate change declined substantially (Figure 3a), because concerns shifted to the financial/economic crisis. Additionally, conservative groups and thinktanks sponsored 'climate change deniers' who tried to reopen the scientific debate by manipulating evidence and intimidating scientists (McCright and Dunlap, 2010). These activities succeeded in creating more doubt in public opinions about climate change.

Policy-makers. International pressure also weakened, because climate negotiations in Copenhagen (2009) failed. In Durban (2011) countries agreed to delay talks about a successor treaty to Kyoto until 2015, which might come into force in 2020.

At the federal level, however, the newly elected (2008) Obama administration strengthened regulatory pressures on automakers. The administration also bailed out Chrysler and GM (in 2009), which went bankrupt during the economic crisis. Using his strengthened negotiating position, Obama secured an agreement on CAFE and GHG emission standards between auto companies, government agencies (EPA and NHTSA), and California. Subsequently, executive branch activity increased sharply (Figure 3b), with EPA and NHTSA accelerating the creation and implementation of mobile GHG-emission regulations and stricter CAFE-standards. The resulting 2009 *Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards Rule* (the 'LDV Rule') created GHG emission standards for light-duty vehicles starting in 2012, which increased 5% per year, until reaching 35.5MPG by 2016 (Figure 5). The rules also allowed California to start implementing the Pavley Act in 2009. In 2011, the Federal government, California and automakers agreed on long-term GHG/CAFE standards (Lutsey, 2012), which would increase to 54.5MPG by 2025 (Figure 14). These GHG regulations remain weaker than those in Europe (and Japan), which is considering 95 gCO_2/km (c. 60MPG) for 2020.

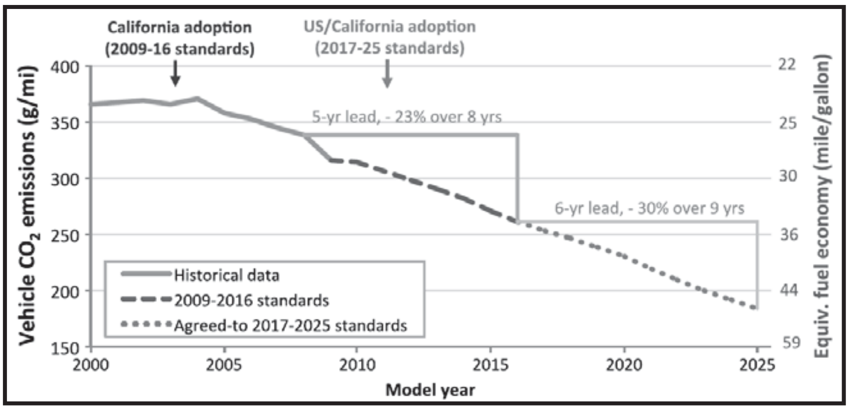


Figure 14: Development of GHG emissions/CAFE standards (Source: Lutsey, 2012)

Obama not only tightened regulations, but also supported green innovation. As part of the 'green stimulus' programme, he promoted a domestic battery industry, issuing $5-billion in grants and loan guarantees to battery makers, entrepreneurs, major auto companies and equipment suppliers (Dijk et al., 2013). Obama also promised to bring one million PHEVs and BEVs to the road by 2015, signalling a shift in federal technology priority from hydrogen/fuel cells to battery-electric vehicles (Bakker *et al*., 2012).

The stalemate for the California ZEV-regulations was unlocked by the 2007 Supreme Court decision and 2009 Obama deals with the automakers. CARB also modified the regulations to accommodate PHEVs (and hydrogen-fuelled ICE-FCVs). CARB created an Enhanced AT PZEV category (Enhanced Advanced Technology Partial Zero Emission Vehicles) and a new compliance path for 2012-2014, which allowed carmakers to sell 7,500 FCVs + c. 58,000 'Enhanced AT PZEV' instead of 25,000 FCVs. A 2012 amendment further increased requirements for ZEVs and PHEVs to 15.4% of annual sales in 2025 (CARB, 2012) (Figure 15). Nine other (East and West Coast) states began procedures to also adopt a ZEV-mandate.

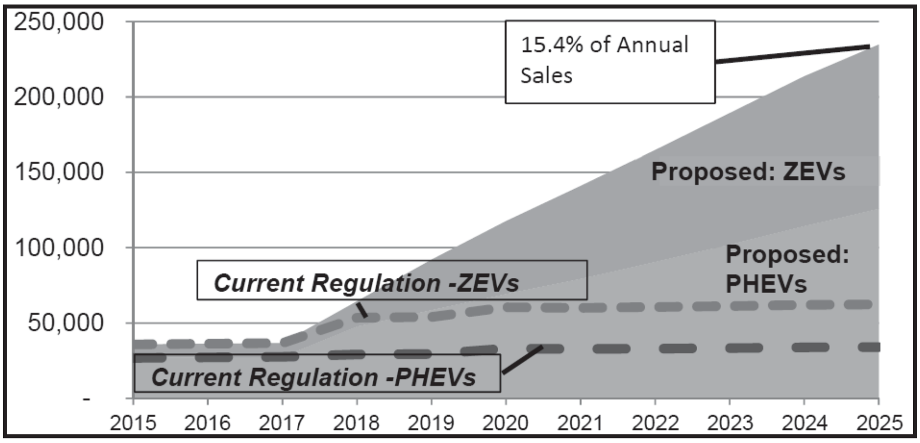


Figure 15: Amendments to California's ZEV regulation (Source: CARB, 2012)

5.5.2. Car industry issue responses

Socio-cultural strategies. To increase the chances of Federal bailouts, American automakers tried to enhance their social and political legitimacy by subscribing to environmental and fuel economy expectations. GM's first Viability Plan (December 2008), for instance, claimed that: "General Motors well understands the challenges to energy security and the climate (…) and believes that (…) we must look to advanced vehicle technologies to reduce petroleum dependency and greenhouse gas emissions" (p. 4). With the surging interest in electric vehicles, automakers also showcased PHEV and BEV concept-cars such as the Chevy Volt. The first Viability Plan therefore included ambitious investment plans in green technologies (Table 5).

Technology	Fuel economy improvement impact	2009-2012 Investment
Hybrid (BAS+)	12-15%	$467 M
Strong hybrid (large vehicle)	30-35%	$515 M
Strong hybrid (small vehicle)	35-55%	$315 M
Extended range electric vehicle (e.g. Volt)	100-120%	£758 M

Table 5: Investment plans in GMs first Viability Plan (2008)

The Viability Plan was reviewed by the *Presidential Task Force on the Auto Industry* (ATF), which Obama created for fear of being accused of interfering with day-to-day management. The Auto Task Force rejected the focus on green cars, because of limited financial prospects.[12] GM's second Viability Plan (2009) therefore paid less attention to green innovation and did not include green resource allocations.

Political strategies. Because Detroit automakers needed Federal funds for survival, they became more cooperative towards environmental regulations and signed up to various substantial CARB and CAFE agreements. But by 2012 they resumed defensive political strategies, arguing and lobbying against the ZEV-mandate. An industry petition to EPA against California's regulation argued that: "It is impossible to predict today whether infrastructural developments, oil prices, consumer confidence and other factors will converge such that automakers will be able to persuade buyers to [buy sufficient numbers of electric-drive cars]. Current data and trends suggest that it is highly unlikely that the industry will be able to meet that mandate" (cited by *Automotive News*, 12/03/2012). Automakers also opposed the Californian ZEV-mandate in an attempt to discourage nine other states from adopting it.

Innovation strategies. Before the crisis Ford and GM displayed BEV and PHEV-prototypes (Chevy Volt, Ford Airstream). GM even announced production plans for the Volt, signalling a shift in strategy from fuel cells to EVs. The financial crisis created delays, because the Auto Task Force was unenthusiastic about the Volt. But in 2010 the first Volt rolled off the factory production lines.

Following the (re)established Californian ZEV-regulations, automakers announced BEV commercialization plans to meet required sale-quotas. The *Green Car Reports* (a consumer-support website for green cars) qualified many models (Chevrolet Spark EV, Ford Focus Electric, Honda Fit EV, Toyota RAV4 EV, and the Fiat 500e) as 'compliance cars', which are "not meant to lure in consumers, or sell in any kind of volume. They're *only* built to meet California regulations for zero-emission vehicles" (reported on 3/5/2012). These models, which are conversions of existing gasoline vehicles rather than purposively-built BEVs, are sold below cost-price.

Despite the BEV-push, advanced-ICE (and flex-fuel) technologies remained automakers' preferred strategy to improve fuel efficiency, leading to accelerated deployment of aICE technologies

[12] In his memoirs, ATF's director notes that: "We discussed the prospects of the Volt, and it quickly became clear that the car had commercial clay feet. (…) The bottom line was that there was no way for the Volt or any next-generation car to have a positive impact on GM's finances any time soon" (Rattner, 2010:97).

such as variable valve timing, continuously variable transmission, gasoline direct injection, turbocharging, six-speed transmission, cylinder deactivation, and diesel engines (Lutsey, 2012). Market positioning strategies. The $3-billion 'Cash for Clunkers' scheme (2009), which offered consumers $3,500-$4,500 rebates, stimulated demand for HEVs and fuel efficient ICE-vehicles (Dijk et al., 2013). BEVs and PHEVs also entered the market, but sales remained low (Figure 4d; Table 6), because of high prices.[13]

	2010	2011	2012	*Total*
Chevy Volt (PHEV)	326	7,671	23,461	*31,458*
Nissan Leaf (BEV)	19	9,674	9,819	*19,512*
Toyota Prius PHEV	-	-	12,750	*12,750*

Table 6: Sales in the U.S. market of selected PHEV and BEV models (Source: data from http://hybridcar.com and http://green.autoblog.com/, last accessed on 12/4/2013)

Because of the economic crisis general market conditions worsened dramatically. Plummeting sales (Figure 6) caused major financial problems for Chrysler and GM (Figure 7). The government rescued both companies with a managed bankruptcy (2009) and substantial bailout ($8 billion and $30 billion loans to Chrysler and GM respectively), with Chrysler being later acquired by Fiat. All American automakers subsequently restructured (shutting down factories, reducing staff, disinvesting brands), cut costs and returned to profitability.

5.5.3 Pattern-matching (2009-2012) and future assessment (2012-2018)

While most developments in the previous period pointed in the 'right' direction, this period is more ambiguous, because developments point in different directions. On the positive side, this fifth period has some elements of the conceptual phase 4: (a) climate change was addressed at the macro-political level (Obama administration), (b) administrative activity remained high (Figure 3b), (c) the political position of US automakers weakened (because of bankruptcy and bailout), which made them more receptive to social and political expectations about fuel efficiency and climate change, (d) automakers jockey for position with various low-carbon technologies, leading to high patenting activity across multiple categories (Figure 4b). But the period also had 'negative' developments, which fit with phase 3: (1) decreasing public attention (Figure 3a), (2) political attention to climate change decreased after 2009 (Figure 3b), (3) new regulations are not radical and do not create a new market segment, (4) markets for HEV, BEV, PHEV remain small (2-3% of overall sales), (5) automakers remain committed to a-ICE and biofuels/FFV. Although car companies continue to invest in radical green options, they do not fully commit to any of them. This period is therefore best characterized as a 'phase 3½' with conflicting developments.

[13] Even with favourable US$7,500 federal tax credits (and other state incentives), these models cost almost twice as much as similar ICE-models.

For the years until the mid-term review of CAFE rules in 2018, we make the following theory-informed assessment, using concepts from the DILC-model:

- *Policy*: Current CAFE standards are not yet tough enough to accelerate radical green innovations. While policy-implementation activity is currently high (Figure 3b), Congressional attention has decreased since 2009, which suggests that the political appetite for tough legislation may be limited in the coming years.
- *Policies and public opinion.* Strong public concerns are needed to create support for radical policies, which might facilitate a shift towards phase 4 in the DILC-model. But public attention for climate change has been declining since 2007 (Figure 3a). In 2012, public attention to climate change increased somewhat, but a continuation of this trend will be necessary to spur a transition to phase 4.
- *Industry.* Politically, industry actors are likely to continue opposing ZEV-mandates and any proposals for tougher regulations, because these threaten current investments in aICE to comply with recent CAFE standards (Lutsey, 2012). The industry has a track-record of successfully obstructing or delaying policies. In terms of technical implementation, automakers are likely to continue on the path of biofuels/FFV and incrementally improving ICEs, which enables them to meet CAFE standards. "This is a strategy of least-compliance, to meet the regulatory requirements at as low a level of compliance as the regulation allows and with the lowest possible risk to the business" (Wells and Nieuwenhuis, 2012:1685). We do not expect major industry commitment to radical green options in the next few years, because of high risks and costs, low market demand (see below), and because of limited policy pressure. Instead, we expect automakers to continue to hedge and develop capabilities in multiple low-carbon technologies (as visible in their patenting portfolio, Figure 4b). This diversity shows, firstly, that automakers *are* preparing for low-carbon futures, but, secondly, that they remain uncertain about the best long-term option (which delays full commitment as we argued above).
- *Market demand*: Sales of electric-drive vehicles (EDV) declined since 2008, but expanded again in 2012 (Figure 4d). Demand is still relatively small, however, providing insufficient incentive for automakers to take the risk of aggressively developing and marketing electric vehicles. Projections of future sales are uncertain, but even in optimistic scenarios electric-drive markets remain relatively small. In 2009, a positive scenario by DoE (Figure 16) predicted that HEVs might achieve 25% market by the end of the decade, when the stringency of regulations will be ratcheted up (Lutsey, 2012), and that PHEVs might achieve 10% market share by 2030, and BEVs about 5% (Figure 29). These estimates may be rather optimistic. HEV market shares, for instance, hovered between 2-3% since 2007 instead of increasing to 6% by 2012 as in DoE's scenario. If market demand for electric cars remains relatively low, the industry may call for a rollback of long-term standards during the mid-term review (2018) of CAFE rules.

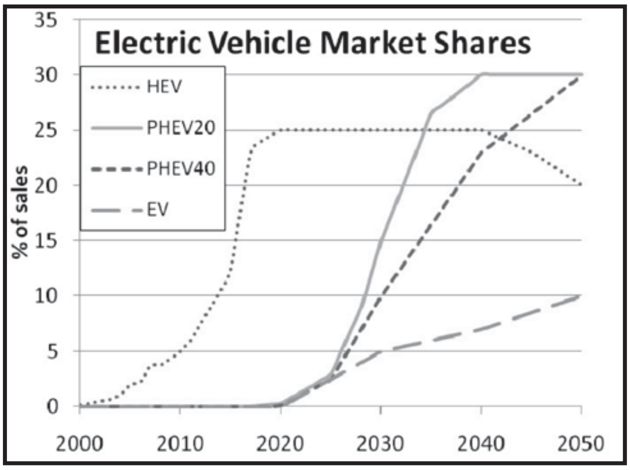


Figure 16: US DoE Multi-Path Study's Optimistic Scenario of Electric Vehicle Market Shares (Source: Gaines and Nelson, 2009)

- *New entrants*. Dynamics may speed up (towards phase 4) if new entrants dedicated to electric drive are successful. *Tesla Motors*, for instance, might drive down production costs and enter larger markets; Tesla has recently forecast first quarterly profits for the 1Q2013. Although new entrants[14] could break the mould of the American automobile industry, they have to compete against powerful incumbents locked into ICE technology, which is still supported by policies, market demand and public opinion.

We therefore expect the climate change issue life cycle to remain stuck in 'phase 3½' in the coming years or even cycle back to phase 3: electric drive market share may build up slowly, but not yet stimulate automakers to fully reorient towards a single solution.

6. Conclusions

The case study clearly showed that the climate change problem and low-carbon technologies co-evolve. On the one hand, the climate change problem had dynamics related to activities from various social groups (scientists, social movements, public attention, policymakers). On the other hand, industry responses and technical solutions had their own complex dynamics, which related not just to R&D investments, but also to broader beliefs, corporate and political strategies. For the paper's empirical goal (assess the degree to which automakers are engaging in low-carbon reorientation), we used the DILC-model to analyse both the 'problem stream' and 'solution stream', and interaction mechanisms over time. We do not expect a perfect match between the ideal-type DILC-model and the complex case, as indicated in section 3. And, indeed, most periods were more complex in the sense

[14] Two other new entrants developing electric vehicles are *BetterPlace* (from California) and *BYD Auto* (from China). The former could change dynamics if its new business model (whereby owners lease 'switchable batteries') is successful. *BYD Auto*, which is planning to sell its all-electric minivan model in the U.S. market for $35,000 before governmental subsidies, could also be a game changer, due to the size of the Chinese market (which could help drive drown mass-production costs), and because it may benefit from substantial state support. Both companies are facing difficulties, however. *BetterPlace* experienced financial difficulties in the last quarter of 2012, and sought emergency funding from investors. And BYD reported a 98% plunge in profits in 2012.

that they contained characteristics from multiple phases. Nevertheless, we were able to give a main qualification of each period in terms of the DILC-model. For the 33-year period, we are thus able to identify an overall pattern, in which the climate change issue lifecycle followed the following phase-sequence: 1 – 2 – 3 –3½ – 3½. This suggests that the fourth and fifth period were stuck between phase 3 and 4, which is the most difficult transition in the DILC-model (entailing radical policies, substantial market demand, and industry reorientation). Especially in the fifth period, developments point in different directions, which may prolong uncertainties and hedging strategies.

This overall pattern suggests that socio-political mobilization is still the core dynamics in the issue lifecycle, and that the main struggle now is to achieve spillovers to the economic task environment. These spillovers are still relatively small, as indicated by relatively small markets and not very tough policies.

To further address green industry reorientation, we look at elements of the industry regime, where some changes have occurred. Firstly, the industry has developed competencies in radically new technologies (fuel cells, electric drive). But automakers have not fully committed to them, giving instead more priority to the elaboration of existing competencies via advanced-ICE and biofuels/FFV. Secondly, industry beliefs have changed somewhat, with automakers no longer denying the climate change problem, and perceiving it as a relevant issue. But addressing climate change has not entered core mindsets or become part of the industry's identity and mission. Thirdly, industry-specific policies have been introduced, initially via technology-development programs (USABC, PNGV, Hydrogen Fuel Initiative), and recently also via CAFE and fuel economy regulations. While these regulations create pressure on the industry, they are not radical policies and allow for compliance with aICE technologies.

In sum, we conclude that regime changes are not yet very substantial or comprehensive. This fits with the DILC-model, which suggests that substantial regime change does not happen until phase 4 or 5 (which the issue lifecycle has not yet reached as suggested above). In fact, the case shows much inertia related to: a) the industry's economic orientation towards and dependence on large, gas-guzzling models, b) the industry's belief that Americans preferred bigger cars, c) policies (in period 2-4) with deliberate loopholes, d) sunk investments in ICE technology, which American carmakers defended with incremental innovation strategies (a-ICE, biofuels/FFV). The innovation races in FCV, HEV, and BEV have begun to undermine ICE dominance. But to avoid risks, manufacturers used "a gradual, contained experimentation [of alternative vehicle technologies], as much as possible anchored within the status quo" (Wells and Nieuwenhuis, 2012:1686).

For the paper's second goal, we propose two conceptual elaborations to the DILC-model. First, DILC-model implicitly assumes that the technical solution becomes increasingly clear as the issue progresses, so that, by phase 4, there is a single, clear-cut option towards which firms can reorient. This did not (yet) happen in the case study, which instead showed continued diversity of technical solutions and successive technology hype-cycles. These characteristics create uncertainties and risks, which, in turn, may delay full industry commitment because automakers don't want commit to the 'wrong' technology. We therefore advance the following proposition which elaborates an implicit assumption in the DILC-model: the shift from phase three to phase four requires the convergence of industry actors (and other stakeholders) towards a dominant solution.[15] The absence of convergence helps explain why the fourth and fifth empirical period did not (fully) move to phase 4. So, while innovation scholars often see diversity as something positive, we suggest that it may also have drawbacks because it may prolong hedging (phase 3) and delay diversification and reorientation (phase 4 and 5).

As a second elaboration we propose to nuance the implicit sequential view of technological reorientation in the DILC-model (incremental innovation, hedging, diversification, full reorientation). Whereas the DILC-model assumes that incumbent firms do not engage in radical innovation until phase 3, the case study showed that automakers already developed and publicly displayed BEVs in the second period (followed by FCV, HEV, and PHEV in later periods). So, rather than a sequential process, radical and incremental innovation co-existed simultaneously in early periods. To explain this deviation, we problematize the distinction between symbolic and substantive action, particularly the idea that technology (only) represents substantive action in the economic task environment. We therefore propose that incumbent firms can use radical innovation as part of political and socio-cultural strategies towards the institutional environment. The case study entailed several examples of this phenomenon:

- In 1990 GM showcased the *Impact* for reputational reasons (which had unintended consequences on CARB's perception of BEVs).
- The industry established public private partnerships (USABC, PNGV) to develop new technologies. Although these PPPs carried costs, they also offered the industry political and reputational benefits: control of technology developments, control over information provision to policymakers, limiting internal competition, enhancing public reputation, signalling that self-regulation was better than formal regulation, signalling willingness to take substantive action, managing technical expectations.
- Toyota improved its green (and innovative) credentials with the Prius, creating an environmental 'halo effect'.
- The industry shaped social and political expectations by parading concept cars and prototypes and making promises about marketing plans. It has a track-record of missing these promises, and deferring new promises further into the future (often 5-10 years).

The paper has shown the usefulness of the DILC-model for comprehensive analyses of societal problems and industry reorientation. In three ways, the analysis of climate change, green cars and industry reorientation goes beyond many existing studies in the innovation field. Firstly, it looks not

[15] The convergence of industry actors also actively contributes to *making* a solution dominant. But firms are not the only relevant actors in creating a dominant design. Other actors (e.g. consumers, policymakers) also make contributions.

only at the ‘solution stream’ (technical innovations), but also at dynamics in the ‘problem stream’. Secondly, it looks not only at innovation strategies, but also at political, socio-cultural and economic positioning strategies. Thirdly, it does not focus on *single* innovations, but looks at *multiple* low-carbon technologies. We suggest that this kind of comprehensive analysis can fruitfully be applied to other grand challenges (e.g. obesity, energy security, food safety) and other industries (agro-food, coal, oil, electricity, pharmaceuticals). We further suggest that the mixed methods approach in this paper is useful to link theory (the DILC-model) and empirical analysis. The quantitative structural-break analysis helps to systematically identify periods for the in-depth qualitative case study. Furthermore, the combination of various time-series is promising to analyse dynamics in both the ‘problem stream’ and the ‘solution stream’. It also takes advantage of the free availability of large datasets accessible via the Internet. These methods could be further explored and elaborated in future research.

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Mutual Reinforcement Dynamics and Sustainability Transitions: Civil Society's Role in Influencing Canadian Forest Sector Transition

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Mutual Reinforcement Dynamics and Sustainability Transitions: Civil Society's Role in Influencing Canadian Forest Sector Transition

Abstract

Socio-technical transition theory and the multi-level perspective (MLP) describes transition trajectories resulting from interactions between niche, regime and landscape levels, addressing how to break "lock-in" of regimes, and highlighting leverage points for transition (Rip & Kemp, 1998; Geels, 2005). Grin (2010) proposes that actors can orchestrate mutual reinforcement dynamics across these levels toward sustainable development. We address three conceptual gaps regarding the agency involved in multi-level transition dynamics, looking specifically at civil society's role. First, the MLP specifies no mechanisms describing regime-level interactions between society, culture, technology, markets and politics (Geels, 2011). Second, the role of non-technical niche innovations (e.g. market-based, normative and political) in regime destabilization and sustainability transitions is neglected. Third, landscape pressures are described both as 'exogenous' *and* as being mobilized by actors onto regimes. The MLP depicts neither direct niche-to-landscape interactions, nor mechanisms whereby agents mediate landscape and regime dynamics. We address these gaps by analyzing how Canadian environmentalists orchestrated mutually reinforcing dynamics in forestry regimes in Canada and influenced global forest products markets. We find these actors 1) generated cross-domain dynamics between markets and domestic policy domains to destabilize and re-structure the regime; 2) cultivated non-technical practices to capitalize on emerging regime opportunity structures; and 3) used markets campaigns targeting global corporations to select and amplify latent landscape values of 'green' consumerism to mobilize pressures onto the regime. These landscape values now influence the regime substantively, suggesting actors have a role in co-structuring landscape trends.

Keywords: Mutual reinforcement dynamics, civil society, agency, cross-domain dynamics, landscape leverage.

1. Introduction

Human activity has created intertwined crises including massive wealth and development gaps between north and south, poverty and hunger, erosion and desertification of agricultural areas, loss of biodiversity, and the twin challenges of peak oil and global climate change. These linked environmental, equity and development challenges above have given rise to the concept of sustainable development, and its companion concept, sustainability (WCED, 1987; Robinson et al., 1990). Sustainability problems are deeply interconnected, elude easy framing, and demand new knowledge and human capacities to guide responses (Carolan, 2004; Hirsch-Hadorn, 2006; Kemp and Martens, 2007). They will also require fundamental transformations of the current structure, culture and practices of societal systems from global to local scales (Gunderson and Holling, 2002; Rotmans & Loorbach, 2008). One way these fundamental transformations are conceived is through the lens of sustainability transitions theory, which is emerging from the field of socio-technical transitions.

This paper is in part a response to calls to better understand the politics and agency involved in such transitions (e.g. Smith, Voß and Grin, 2010), and in part a contribution to exploring the role the agency of global civil society/social movement actors in encouraging sustainability transitions. This paper looks at: 1) how a group individuals acting on behalf of environmental non-governmental organizations orchestrated mutually reinforcing dynamics to influence changes in forest products regimes – in Canada and globally; 2) how these actors generated linked pressures across policy, markets and cultural domains, to build on existing opportunity structures and 3) how these dynamics are triggered by strategies that themselves can be seen as innovations at the niche level and as direct landscape interventions. In the process we will both engage and challenge elements of the socio-technical transitions theory and the multi-level perspective.

2. Conceptual approach

2.1 Socio-technical transitions theory and the multi-level perspective

Socio-technical transitions theory (and now sustainability transitions theory) is focused on understanding trajectories of socio-technical systems development and practical interventions to re-orient such systems towards sustainable pathways. Socio-technical systems are *clusters of elements including technology, regulations, user practices and markets, cultural meanings, infrastructure, and supply networks*. Technology is the focal point for organizing transition efforts, within a co-evolving institutional context (Geels, 2010). Transitions are defined as *transformation processes in which society or a complex subsystem of society changes in a fundamental way over an extended period (more than one generation)* (Rotmans et al., 2000, quoted in Kemp and Rotmans, 2004, p.138). Transition refers to a deep structural transformation from one dynamic equilibrium state to another, caused by co-evolutionary processes. The transitions approach connects to larger sustainability discourses by addressing how to break technological and social “lock-in” of existing regimes, and speed the uptake of sustainable innovations into society.

The related multi-level perspective (MLP) frames transition processes as multi-level interactions between innovative practices (niche experiments), industry/problem domain structure (socio-technical regime), and long-term, exogenous trends (socio-technical landscape) (Schot, 1998; Rip & Kemp, 1998; Geels, 2005). The MLP posits functional and temporal levels of increasing structuration where macro-processes are slower (and more structured), meso-processes are faster (and less structured), and niche-processes are fastest (least structured). Niches generate agency, new practices and norms, and radical innovations, and are structured by incumbent regimes (Rotmans et al. 2001; Geels, 2005). According to this perspective, the landscape provides the broader structural context for niche–regime interactions, and includes social values, policy beliefs, worldviews, political coalitions, the built environment, prices and costs, trade patterns and ecological influences (Kemp & Rotmans, 2004). Landscape processes, political or otherwise, are considered to be exogenous, bearing down on regimes through interpretation by actors (Geels & Schot, 2007), generating stress and creating opportunities - acting as a stability landscape that provides 'gradients for action' (Rip & Kemp, 1998).

Transitions are framed as the scaling up of niche practices or innovations to the regime level. Niche innovations succeed when broader selection environments (regime and landscape) are favorable. In addition to creating protected niches, strategic actors can take advantage of windows of opportunity (Geels & Schot, 2010) and can co-determine what landscape tendencies are mobilized, neglected or circumvented (Grin et al., 2010; Rotmans & Loorbach, 2010). The concepts in the MLP, and specifically the transition trajectories resulting from interactions between levels can be used to highlight different leverage points to tip systems towards sustainability, and situate sustainability transitions as co-emerging through 'circular causality' as processes in multiple dimensions and at different levels link up with and reinforce each other (Geels, 2011).

The relationship between structure and agency is central to socio-technical transitions theory, and theorists draw on Giddens' structuration theory (1984) which describes how structures (rules and resources) are sustained and recreated through agents' routines (practical consciousness) and reflexivity (discursive consciousness), and "the structural properties of social systems are both medium and outcome of the practices they recursively organize" (p. 25). Systems and institutions therefore do not exist independently, but are continually enacted, both constraining and enabling further action. This "duality of structure" implies that structural change requires actors to critically scrutinize and reformulate their conduct in light of intended and unintended consequences (Giddens' reflexive monitoring). This can lead to **Re-structuration**, *a re-oriented co-evolution of mutually reinforcing novel practices (niche experiments) and structural changes (regime changes) towards sustainable development, amidst landscape turbulence* (Grin et al., 2010: 265).

2.2 Agency and mutually reinforcing dynamics

Here, we are interested in actor's roles (agency) in the mutual reinforcement of novel practices, structural/regime changes, and landscape influences. Working from a transition governance perspective, Grin et al. (2010) propose that actors can advance 'constructive interference' between levels, to orchestrate the process of mutual reinforcement toward sustainable development. From this perspective, the agency necessary to connect and mobilize these alignments is characterized as a distributed competence for strategic agency, whereby actors extend their agency by viewing issues from a meta-perspective to see immediate opportunities and limitations as well as wider patterns in space and time. Grin et al. (2010) describe three aspects of the strategic agency involved in orchestrating mutually reinforcing transitions towards sustainable development. These are 1) envisioning and advancing novel practices at the niche level; 2) opening up new institutional structures in relation to regime and landscape constraints/opportunities; and 3) sustaining ongoing connection between novel practices and new institutional structures to create a cycle of mutually reinforcing change. Restated simply, agents make structural change and innovative practices relate to one another, and have the power to block or emphasize various structural influences to advance innovation (Grin et al., 2011).

2.3 Concepts for further development in the MLP

Despite the impressive theoretical advances made by scholars working with socio-technical and MLP approaches, this paper attempts to fill some conceptual gaps to do with the agency involved in the dynamics and mechanisms of transitions across levels. First, the MLP framework does not identify substantive mechanisms to describe the interactions between society, culture, technology, markets and politics that make transitions possible (Geels, 2011). Grin et al. (2011, 2010) describe mutually reinforcing dynamics and the role of agency in building this reinforcement, but there is considerable work still to be done to flesh out how such co-emergent reinforcing dynamics can be catalyzed and orchestrated by actors, particularly across the complex problem domains involved in sustainability transitions.

Second, the practical application of the theory remains focused on the role of niches in the development of socio-technical novelty, and the transition pathways involved in their scaling up to achieve regime transition. To understand the full suite of actions and dynamics involved in achieving sustainability we need to go beyond protection of socio-technical niches, at least in how they are currently construed as protected spaces for path-breaking technological innovation to emerge. Sustainability transitions theory can benefit from more robust concepts for how non-technical aspects sustainability niches of all kinds emerge and become institutionalized. This broader conceptualization of the niche level as the site for emerging social innovations can enable greater clarity about the market-based, cultural, normative or policy/governance aspects of niche development. In order to analyze transitions more fully, analysis must also go beyond looking at the role of policy or technology actors to describe the agency of those acting on behalf of firms, civil society organizations and consumers in advancing such transitions.

Third, within existing depictions the MLP and transition pathways (Geels, 2002, Geels and Schot, 2007), we find the concept of landscape to be problematic. The landscape is portrayed as “exogenous”, yet according to structuration theory (Giddens, 1984) there is continuous interplay between structuration processes and agency, at all levels. Key to the question of agency, the MLP depicts no mutual influence between niche and landscape levels, emphasizing bottom-up change from niche-to-regime (Berkhout et al., 2004), and the landscape itself is not depicted as influenced until a new regime established. However, actors are described as having the ability to co-determine what landscape tendencies are mobilized, neglected or circumvented, and in what way (Grin, 2010; Grin et al., 2011). For instance, Grin (2010) describes civil society as the context that shapes or articulates consumer preferences. A primary role of social movements is to strategically select, frame, mobilize, and amplify landscape pressures and bring them to bear on particular (more vulnerable or open) aspects of the regime. Concepts are needed within the MLP to describe these broad political and normative mobilization activities and the resultant influence of civil society on transition trajectories. Conceptualizing these activities as niche practices influencing a regime conflates invention/innovation activities in a socio-technical niche with political activities that selectively amplify and mobilize particular landscape developments and strategically direct these pressures to de-stabilize incumbent regimes. In the absence of concepts to describe the agency involved in landscape pressure mobilization, landscape developments may be assumed to be exogenous to the influence of actors when they may not always be.

2.4 Theoretical Contribution

In this paper we will argue for a broader framing of innovation to include social innovations toward sustainability. Social innovations are complex processes of introducing new products, processes or programs that profoundly change the basic routines, resource and authority flows, or beliefs of the social system in which the innovation occurs (Westley and Antadze, 2010). A social innovation framing conceptualizes the many facets of transitions to sustainability. Social innovations are somewhat more difficult to trace, due to their intangible nature, and are often embedded in the rules and relationships that structure or restructure social interactions at all scales. To understand them fully, how they emerge, and how they ultimately reshape both regimes and landscapes, we need in-depth case studies.

Here, we look at a case spanning more than twenty years that affects the forestry industry in Canada. We will use the case to illuminate the need for further conceptual development in the following areas:

1. The case offers greater insight into how actor networks created reinforcing dynamics, across domains of markets, policy, and culture. In addition to brokering and mediating dynamics between levels, civil society actors in this case generated mutually reinforcing dynamics across different, linked, institutional domains. These activities involve capitalizing on emerging structural opportunities or constraints, and orchestrating connections within different domains within the regime, as well as between levels;
2. We explore the creation and linking of non-technical niche practices (i.e. social innovations) in markets, firms, environmental organizations, and policy arenas which impacted the forestry regime in Canada; and
3. We focus on the agency of social movement actors, arguing that because they are often marginal to the rules, authority and resource structure of the regime, they have a unique capacity to frame and respond to lock-in at the regime level, by mobilizing landscape pressures to disrupt the regime and create readiness for transition. We introduce the notion of *landscape leverage* to describe how campaign strategies sought to select, frame and amplify trends at the landscape level, and then translate and direct them onto the regime. The case suggests that that landscape level dynamics may not always be exogenous to the influence of actors, and that niche-to-landscape and agent-directed landscape-to-regime interactions may be as important to understand as niche-to-regime interactions.

3. The Case Study: Canadian Forest Conservation Campaigns 1990-2010

3.1 Introduction to the Case: Global and Canadian Forest Campaigns

Below we describe how civil society, in this case a trans-national coalition of environmental organizations (ENGOs), has orchestrated mutually reinforcing dynamics through their campaign activities. Canada has been the site of ongoing political struggles over the use and conservation of forests, in particular on the west coast of British Columbia where rich temperate rainforests were being clearcut at alarming rates in the late 20th century (Stanbury, 2000). The forestry regime extends from forest ecosystems to the consumer, and includes public policy and politics, industrial paradigms and practices, market institutions and standards, and dominant forest products extraction and production technologies, and diverse experiences of the cultural significance of forestry and forest products. Since the mid-1990s, forest activists in Canada have established an array of innovative campaign strategies which link across regional and global scales in order to protect endangered forests, by harnessing the power of the marketplace to break through the political and industrial lock-in of forest regimes and institutionalize sustainable forest management practices. As we shall describe, in the evolving conflict between industry, government, First Nations (indigenous groups) and ENGOs, the latter have gained new points of influence and power. A network of environmental actors within several ENGOs began considering forestry regimes from a wider perspective in order to escape lock-in. They followed the supply chain from local systems of resource extraction and forest policy administration, tracing the distribution of forest products to their purchasers in globalized wood and paper markets, and finally to large retailers and to consumers. Within this supply chain, politically, ethically and financially vulnerable points were identified, along with strategies to exploit them in order to advance their environmental and systems-change goals.

3.2 Forestry transition in Canada – from Clayoquot Sound to the Boreal Forest

Canada leads the world in exports of lumber, pulp and newsprint, but is also one of only three countries in the world, along with Brazil and Russia, with significant amounts of intact forestland remaining (Bryant, Nielsen, and Tangley, 1997). The forest industry has historically been a crucial part of Canada's resource economy, both through export earnings and in its role sustaining jobs in small isolated communities. Canada's forest products exports comprise 1.8% of the overall GDP and almost 12 percent of the manufacturing GDP (NRCAN, 2011). This export dependency, especially to the United States, has made the industry vulnerable to economic upheavals, particularly the loss of lumber sales due to upheaval in cycles of residential housing starts in the US. Many in Canada consider that the last decade has been the worst crisis in the forest industry's history, with mill closures, poor financial returns, and enormous job losses. In the year 2000 the Canadian forest sector supported 367,400 direct jobs, and by 2010 this had declined to roughly 200,000 (NRCAN, 2011). Partially in response to these declines, the industry has been pursuing an agenda of diversification by investing in bioenergy, biochemicals and other innovative forest products, as well as targeting emerging markets.

Other landscape level patterns influencing the Canadian forest sector include changing demographics and consumption patterns, the rise of fast-growing southern plantations, and growing competition with other materials (FAO, 2011). Along with changing labour and regulatory pressures globally, these dynamics have caused significant change in the structure of the Canadian forest sector over the last several decades, highlighting the need within the industry to invest in product innovation and gain competitive advantage for Canadian forest products.

3.3 Transition and transformation in Canadian forests regimes

Canada's forestlands are 93% publicly owned and are administered by provincial authority through long-term tenures, making certainty of access a primary concern for industry. Forest companies, provincial governments and unions interests interlock in powerful regimes with incumbent benefits in the form of government income from taxation and 'stumpage fees', industry export income, and high-paying union employment in remote, vote-rich regions. The dominant forestry paradigm emphasized streamlined regulation, high yields, and mechanization – with logging undertaken by vertically integrated companies who owned rights to the trees, mills, and export infrastructure. Historically, forestlands were managed intensively with clearcutting as the predominant logging practice. Parks creation often occurred in areas less desirable to industry, or in places with aesthetic beauty but containing little biodiversity and few economically valuable forestlands. This fuelled community-based and environmental protests across Canada, and a so-called "War in the Woods" which pitted environmentalists against the incumbent forestry regime (Stanbury, 2000).

The environmental movement's growing focus in the 1990s on global forest product markets and forest certification provided a way to connect up local forest struggles to wider work on market transformation, which could influence regime change. In Canadian forests, conservation struggles took the form of communities protesting clearcutting, landslides, fresh water and fisheries impacts, environmental activists blocking roads, and First nations launching rights and land title challenges (Stanbury, 2000). With government, firms and environmentalists all looking for a way to go beyond "valley-by-valley" conflicts, comprehensive multi-stakeholder land use planning gained political favour in the 1990s in some Canadian provinces. This reproduced many of the existing regime structures, and only incremental gains towards sustainable forest management were made.

In BC, the high profile failure of land use planning in Vancouver Island's Clayoquot Sound catalyzed more than ten thousand Canadians to protest, resulting in over 900 arrests during the summer of 1993 (Stanbury, 2000). Protests in Clayoquot were the largest expression of civil disobedience in Canadian history up to that point, yet achieved little policy change. When government could not be persuaded to stop clearcutting in Clayoquot's last intact valleys, environmental leaders took their message internationally. Greenpeace and their allies followed the trail of logs and money to big brand name companies that were buying forest products from Clayoquot, creating the first markets campaigns against forest products. This involved threatening to boycott the brands of Scott Paper and Pacific Bell telephone for destroying Canada's ancient rainforests to make toilet paper and phone books (Berman, 2011). These brands cancelled contracts with the company operating in Clayoquot, which caused the company to stop logging and engage in negotiations directly with environmentalists – something ten thousand protesting Canadians had been unable to accomplish. Within several years, negotiations led to the main forest company in the region announcing it would stop all clearcutting in the ancient rainforests and protect the remaining unlogged valleys, and the Clayoquot Sound Scientific Panel was established to apply new conservation and ecosystem-based management in the forests (Stanbury, 2000).

The invention in Clayoquot Sound of targeting the high-profile brand customers of forest companies, using this as leverage to negotiate with companies to change logging practices and protect endangered forests, and translating these agreements into new policy (using the threat of markets reprisals and the lure of a win-win situation) became a model that was scaled up, honed and repeated across Canada by markets campaign groups. A coalition of ENGOs expanded their international and provincial campaigns northward to protect the last significant remaining coastal rainforest in BC – an area environmentalists christened "the Great Bear Rainforest". High-profile markets campaigns targeted wood and paper products originating from endangered forest regions worldwide, using the Great Bear Rainforest as the 'poster-child'.

From 1994-2000, markets campaigns to protect the Great Bear Rainforest met with increasing success. Campaigns targeted customers of BC wood products in U.S., European, and Japanese markets worth roughly one billion dollars (Smith and Sterrit, 2007), and hundreds of millions of dollars worth of contracts were cancelled with forest companies operating in BC's coastal rainforest (Riddell, 2009). Over 80 companies made commitments to phase out endangered forest products, including Home Depot and Lowe's, the world's largest wood retailers, IKEA, and Fortune 500 companies Nike, Dell and IBM (Riddell, 2005; Smith and Sterrit, 2007). German and US buyers registered concerns with the government and industry, signaling that a solution to the conflict had to be found. Due to financial pressure and the related controversy, forest companies operating in the Great Bear Rainforest entered into direct bi-lateral negotiations with ENGOs, bypassing the provincial government process that continued to resist significant regime change. In negotiations between forest companies and ENGOs, high levels of conservation were agreed to, and company commitments to pursue Forest Stewardship Council-certified logging in the remaining areas to meet stringent new sustainable management requirements. Negotiations expanded to include First Nations and regional stakeholders, and the resulting agreements were finally advanced through the official land-use planning process. In 2006, the province announced the Great Bear Rainforest Land Use Decisions - representing a significant institutional shift to ecosystem-based forest management, with over 1/3 of the region (more than 2 million hectares) protected from logging. New legal designations were created to allow First Nations cultural uses in protected areas, and a conservation fund of $120 million was to finance ecosystem protection and support sustainable First Nations businesses (Price et. al, 2009).

After the success of the Great Bear Rainforest, the model of using markets campaigns to destabilize regimes and create innovation opportunities became widely embraced by the ENGOs who developed this new strategy. Greenpeace International uses the story and strategies honed in the Great Bear Rainforest when training new campaigners across their global organization. Wielding and advancing the marketplace campaign power in order to change forest products markets and gain protection for endangered forest regions through policy also become institutionalized practice for other markets campaigning organizations such as Rainforest Action Network (who also focus on tropical forests and the US), ForestEthics (who have applied the model to Chile, US public lands, and elsewhere), and Canopy (a spin-off solutions group that focuses on shifting the Canadian publishing industry and protecting Indonesian forests). Many of these organizations or the individuals involved are also now applying this model to climate change issues and the challenge of re-orienting energy regimes (Berman, 2011).

As the need for market-place pressure in the Great Bear Rainforest receded, ENGOs redirected the leverage generated by markets campaigns yet again – eying the largest prize remaining in Canada – the vast northern Boreal forests. Canada's Boreal forest is the world's largest intact area of forest and wetlands, about 310 million hectares in size. This forest encompasses the traditional territory of about 150 First Nations, and the land and resources of the Boreal are critical to their cultures and their future. The Boreal forest contains over one million lakes, is the breeding ground of billions of migratory songbirds, and is home to the iconic and endangered woodland caribou. More than 208 billion tonnes of carbon are stored in the Boreal forests trees, soils, wetlands and peat - equivalent to 26 years' worth of global greenhouse gas emissions.

Pulp derived from the Boreal forest was sought after by big brands in the magazine and paper industry, including Victoria's Secret lingerie, and Kleenex tissues. Greenpeace targeted Kimberly-Clark's Kleenex brand through their *Kleercut* campaign. Weyerhauser and West Fraser Timber Co. who logged in Boreal caribou habitat faced ForestEthics' campaign against Victoria's Secret and their popular mail-order lingerie catalogues. Victoria's Secret mailed one million catalogues per day, sourced primarily from Canadian Boreal old growth (Berman, 2011). This campaign, dubbed "Victoria's Dirty Secret", featured a newspaper 'subvertisement' of a bustier-clad woman wearing Victoria's Secret trademark angel wings and holding a chainsaw, calling on the company to stop destroying forests.

During this time, Canada's federal government had introduced a Species At Risk Act, which would require caribou recovery plans be implemented, and several provinces were advancing land use planning processes for the Northern Boreal region. The Forest Products Association of Canada (FPAC), who represented 21 of the largest forest products companies in Canada, had been greening its image and pursuing forest certification and ambitious carbon reduction strategies. In light of over a decade of poor financial returns, the opportunity to gain competitive advantage by branding Canadian wood as ecologically sound was a motivating factor for FPAC and its member companies. The industry was also aware of the impacts that climate change could have on the valuation of forests, and their increasingly important future role both as carbon sinks and energy sources. They perceived potential benefits by proactively engaging these issues in partnership with the environmental community. In 2006, Victoria's Secret's parent company, Limited Brands, declared they would stop buying Boreal-sourced pulp. At this point four of the eight major operators in the Boreal forest were facing campaigns against their products, and the entire Canadian brand was at risk in the marketplace.

In 2008, FPAC and 21 forest companies, encompassing virtually all of the Canadian forest sector entered into interest-based negotiations with a coalition of 9 ENGOs to solve their conflicts and identify innovative solutions. Two years later, in May 2010, the parties came to formal Agreement. Touted as the "largest conservation agreement the world has ever seen[i]", the Canadian Boreal Forest Agreement (CBFA) was signed to position Canada's Boreal Forest as a world-class model for sustainable forest management and conservation. It encompasses 72 million hectares of public forests licensed to FPAC member companies. Agreement goals would advance world-leading forest practices (to exceed FSC standards) and land protection, support recovery of Woodland Caribou and other species-at-risk, reduce greenhouse gas emissions, improve forest sector prosperity, and create marketplace recognition for CBFA signatory companies. The larger parts of the Agreement need provincial consent/regulation and sometimes First Nations consent, which is an enormously complex undertaking that would require governments in 8 jurisdictions to legislate new land use designations, including creation of large protected areas. The Agreement is still in the early stages, and the full systemic impact is not yet known, due to its complexity and short history. However, as of just prior to the three-year anniversary in 2013, no endangered forest had gained legal protection. In the latter part of 2012, and early 2013, two of the three markets campaigning groups left the Agreement (Greenpeace and Canopy), due to its slow progress in meeting milestones, and a lifting of the logging suspensions in 2012. The remaining signatories are maintaining their support for the Agreement, but it has faced difficulties in funding and gaining political outcomes from the outset.

4. Discussion and Analysis

4.1 Reinforcing dynamics across different domains

The ENGOs in this case were successful in disrupting the stability of forestry regimes and introducing innovative sustainability practices and rules both at the regional level, in the case of the Great Bear Rainforest campaign and the ensuing policy implementation of the Agreement, and at the national level, through engaging the entire Canadian forest sector in the Canadian

Boreal Forest Agreement. To break the lock-in of the existing forest regime, global marketplace strategies were necessary. Tarrow (1998) refers to the opportunities and constraints facing social movements due to co-emergent institutional dynamics as “political opportunity structures” - institutional conditions that may enable or block political and regulatory changes being advocated for by social movement actors (also see Elzen et al., 2011). A similar “industry opportunity structure” has been defined (Den Hond and De Baaker, 2007) related to economic, organizational and cultural features that constrain or enhance the ability of firms within an industry to change their behavior, including for example, cost structures, level of competition, and customer preference. This notion can also be expanded to describe how social movement actors respond to the “normative opportunity structures” created by cultural and values changes at the landscape and regime levels. ENGOs in this case advanced sustainability transitions by skillfully building on political, industry and normative opportunity structures. They did this largely through framing and discursive strategies, and selectively mobilizing values of consumers and key firm stakeholders – using the power of global brands to gain attention and elicit consumer response in favour of greener products and practices.

By capitalizing on changing cultural values and global and domestic financial pressures on the industry, ENGOs connected to the opportunity structures that were present, and then amplified these pressures to create openings for new policies and institutions. We will refer to these coordinated efforts to create pressure on different parts of the regime as cross-domain strategies. Cross-domain strategies included both the creation of novel structures, and co-opting existing regime structures to advance sustainability innovations. The success of Canadian forest campaigns began with activists’ insight that the political domain at home was locked-in, and they could target specific firms *and* the domestic forestry regime through strategies directed at the global marketplace for wood and paper products. In the absence of domestic political opportunity structures environmental actors shifted their focus towards mobilizing new global norms to create political leverage through financial threats to industry. Interestingly, these strategies were necessitated also by the *absence* of effective global governance structures guiding forest management, which was in itself a form of political opportunity structure. However, for environmentalists to capitalize on this absence, forms of cultural and industry/marketplace leverage had to be created. For a period of time, ENGOs de-emphasized political work, and instead built on and cultivated emerging green consumer values globally using campaign messages and organizing tactics, using this to amplify the financial pressure being felt by the Canadian forest industry as a result of broader changes in forest products markets (such as declines in US housing starts and competition from fast-growing southern plantations). The forest campaigns and regime influencing activities advanced by Canadian and international ENGO were complex and used multiple strategies – illustrating what Grin et al. (2011) refer to as distributed competence for strategic agency. The primary opportunity structures accessed by ENGOs and then co-created through cross-domain strategies were those with industry, although later in the campaigns political opportunity structures were necessary. Industry opportunity structures were opened up and capitalized upon using the following strategies: a) globalized forest campaigns; b) market campaigns; and c) forestry certification. These were pursued by environmentalists as cross-domain strategies, building on and reinforcing cultural values in support greening of forest products, and acting as a financial threat/incentive to the Canadian forest industry and policymakers to re-orient regime practices and regulations to advance sustainability.

a) Globalized forest campaigns

McAdam et al. (1996) highlight how certain political situations facilitate social movement activity. Campaigns created by environmental non-governmental organizations (ENGOs) in order to protect global forests exemplify a pattern observed by global governance theorists. Social movements have increasingly responded to unsustainable patterns of resource extraction and regime lock-in at domestic/state levels by moving to international governance contexts and partnering with more powerful NGOs (Keck and Sikkink, 1998; Sonnenfeld, 2002). This is particularly so when they are seeking to influence trans-national corporations and markets, as in the forest sector (Bernstein and Cashore, 2010; Gritten and Mola-Yudego, 2010).

As the extent of global forest destruction became apparent in the 1970s and 1980s, public concerns grew over impacts of deforestation, clearcutting, loss of biodiversity, and effluent from pulp mills (Gereffi et al., 2001). ENGOs developed market-based strategies in the mid-1990s in direct response to the inability of nation-states to protect social and environmental interests within the context of increasingly globalized markets and a lack of international regulation. ENGO forest campaigns have become distinctly effective because they combine different strategies and easily shift between places and scales, in response to the challenge of globalization (Miller and Martin, 2000). This includes the use of non-violent direct action to stop or restrain industrial actors, consumer boycotts, public education and lobbying (Affolderbachs, 2011). Mol (2000, 49) observes that in order to maximize gain, ENGOs engage in strategic networking as a constant dynamic process with rapidly changing partners and opponents. Globalized ENGO forest campaigns generate leverage through cultivating strategic alliances with brokers and intermediaries and manipulate their opponents' range of action through local-to-global coalitions and networks (Affolderbachs, 2011).

Focusing on global markets enabled international ENGOs such as Greenpeace, WWF and Friends of the Earth, which have broad communications and campaign reaches, to connect unsustainable consumption patterns in northern industrialized countries to unsustainable resource extraction in less regulated states. ENGOs have focused on two dimensions in their international attempts to change forestry regimes – work to shift the practices of forest companies and impact global supply chains through boycotts and markets campaigns, and the development of third-party certification for forest products (Bernstein and Cashore 2007; 2010). This international markets work was linked to local forest struggles, perhaps most effectively in Canada from the development of such strategies in 1994 until 2010, when 72 million of hectares of forest was earmarked for a transformation in management through the Canadian Boreal Forest Agreement – the world's largest forestry agreement.

b) Markets campaigns

Through marketplace-focused campaigns, ENGOs critique products and production practices, seek to reduce sales of controversial products, and attempt to build markets for environmentally or socially responsible products (O'Rourke, 2005). Such campaigns also aim to shift market demand away from controversial regions and advance innovations in sustainable forestry – through changing practices, planning guided by ecosystem-based management and adaptive governance approaches, and comprehensive protected areas creation. New practices at the firm level involve defining criteria for "good wood" products, detailed supply chain tracking, and adoption of procurement policies which give purchasing preference to recycled and alternative fibres. ENGO forest campaigns also demand that companies purchase products that are third-party certified by the Forest Stewardship Council.

ENGOs campaigns generate financial and political power by harnessing markets towards sustainable forest products. A key strategic leverage point is building market demand by targeting high profile, highly branded corporations (e.g. Nike and other Fortune 1000 companies) as well as leading brands in key consumption sectors: Home Depot and Lowe's in solid wood/lumber, Staples and Office Depot in office paper, Scott Tissue and Kleenex, and Victoria's Secret and L.L.Bean in the catalogue market. ENGOs select campaign targets based on a brand's perceived vulnerability to campaigns, and because the company is purchasing products sourced from forest companies logging operating in contentious areas. Consumer boycotts and media campaigns are orchestrated against the big brand company, calling on them to stop purchasing from 'bad actor' forest companies. Campaigns act to frame and amplify existing ethical concerns held by consumers in order to influence company behavior, while also influencing consumer preference more broadly through shaming 'bad actors' and showing visual, compelling images of wilderness and wildlife such as British Columbia's iconic "Spirit bear" and endangered woodland caribou. Campaigns also depict the destruction of forests caused by 'bad actor' forest companies who are supplying the big brands. The brand-focused market campaigns have become known as "blanket campaigns", because they focus on the global financial partners and leaders within a given firm including shareholders and investors (Gritten and Mola-Yudego, 2010). Once leading firms in a sector have succumbed to campaigns and adopted more sustainable buying practices, their competitors in the same sectors are targeted. In this way, market campaigns act as a vehicle to speed the adoption of Forest Stewardship Council-certified products, as well as increasing demand for recycled fibres and alternatives such as bamboo, straw and agricultural waste. They also create intense pressure on targeted forest companies, who suffer contract cancellations, shareholder pressure, and negative media. In the case of Canada's rainforests and boreal forest, this pressure spilled over onto other industry actors, and the government who was regulating and dependent on stumpage income. In the early stages, government and industry associations invest in costly PR battles, and large amounts of senior leadership time is spent combatting the threat of boycotts and brand damage. In this way, markets campaigns act to destabilize industry, market, and policy regime actors and increase the financial, political and societal risks of maintaining the status quo.

c) Forest certification – creation and advancement of FSC

In 1993, the Forest Stewardship Council (FSC) arose as the first third-party certification system in international markets, after the global convention on forests failed to be ratified (Bernstein and Cashore, 2010). Led by Greenpeace and WWF, its creation was intended to curtail logging in endangered forests and advance new rules and practices. FSC has core principles guiding 'on the ground' operations, and requires chain of custody tracking. It has three representative chambers: social, economic and environmental. Governments are not represented. FSC certification created binding and enforceable rules to advance sustainable forestry practices, effectively acting as a private form of international governance, deriving authority directly from participating firms, NGOs and other interested parties, and not from sovereign states (Cashore, 2002; Bernstein and Cashore, 2007). Since 1993, several other industry-friendly certification schemes have arisen to challenge FSC, but it remains the sustainable brand of choice for the global network of ENGOs engaged in market campaigns, and is seen as the most environmentally and socially credible certification.

Certification has been described as an institution that has transformed power relations in the global arena by linking diverse (sometimes antagonistic) actors across local, national and international levels to govern firm behavior in a global space that had previously eluded the control of states and international organizations (Gereffi et al., 2001). The power of certification to influence regimes is potentially significant. Bernstein and Cashore (2007) report that current certification systems operate in sectors that represent one-fifth of the products traded globally. The Forest Stewardship Council is the oldest and one of the most successful forms of such of third-party certification (along with Organic and Fair Trade labels). While FSC was intended primarily as a mechanism to address tropical deforestation, its uptake has been much greater in northern countries, with Canada leading the way. By 2008, Canada had more FSC-certified land than any other country – at 25% of the world total, and 25 million hectares (NRCAN, 2008). While competing industry-sponsored certifiers such as CSA and SFI had greater volume, FSC was winning the public relations battle – becoming a preferred choice of values-sensitive European markets, and dominating the global paper market.

d) Orchestrating cross-domain and mutually reinforcing dynamics

Marketplace campaigns targeting Canadian firms aimed to revoke the social license of firms to operate, and to generate financial pressure on companies to do what is in their power to stop destructive practices and engage in re-structuring the regime. Discursive and markets efforts mutually reinforced each to create a climate of destabilization within industry and governments. Canadian policy-makers had to respond to the public's and environmentalists' concerns about caribou extinction, in the case of the Boreal campaign, but also to communicate to the international marketplace that Canada was fulfilling its responsibilities to govern forests in a sustainable manner. In each of the campaigns described above, environmentalists arranged visits from disgruntled commodity purchasers who did not want to be given a 'green-washed' story from government public relations people, and who threatened to cancel contracts if politicians did not signal a radical restructuring of provincial-level forest policy.

Fundamental to these global marketplace strategies was their connection to regime actors and institutions within in Canada, and the political leverage they conferred upon ENGOs domestically. New policies and significant changes in industry practices on-the-ground were necessary in order to conserve forests. Using the threat of markets reprisal to gain power, ENGOs participated in direct negotiations with the forest industry, which led to reframing many of the assumptions guiding the forest industry and adoption of sustainability as a central principle. ENGOs also pursued domestic political strategies of public mobilization and participation in government-sanctioned planning processes from their new position of power. It is the linkage between these markets-based approaches and the political and policy engagement domestically that enabled rules to change, resources to flow towards innovative practices, and new a culture of collaboration to emerge between ENGOs and forest companies seeking to gain positive branding and avoid boycotts. In addition to brokering and mediating dynamics between levels, civil society actors in this case generated mutually reinforcing dynamics across cultural, market and policy domains. These activities involved capitalizing on emerging political and industry opportunity structures and connecting pressures coming from both new niche practices and from landscape level trends. Powerfully framed stories of destruction and opportunity to do good were central to work in both domains, and these drew upon and deepened the normative opportunity structure created by growing consumer awareness and concern about environmental problems.

Another cross-domain dynamic that enabled regime transition was the interplay between creating new institutional openings, and working with those already present. Within the connected domains of politics and markets, ENGOs both advanced novel structures and institutions, and co-opted existing ones. Within the forest industry and marketplace, new structures took the form of Forest Stewardship Council Certification, which required that innovative forestry practices take place. This new structure, however, fit with existing marketplace functioning and norms, speeding its acceptance and making its adoption easier for firms, especially if they were being targeted by boycotts. In the policy domain, ENGOs co-created new structures for direct bi-lateral negotiations with industry, as a forum to find systemic solutions and test innovative practices. They also co-opted existing regime structures by folding their agreements into official government planning processes. The combination of creating new structures and co-opting existing ones in both markets and policy arenas enabled highly novel forest management practices to be institutionalized.

4.2 Non-technical niche practices

In order to advance structural or regime-level change, new practices were required to replace the less sustainable incumbent practices. These new practices were not technological in nature, and differed across domains and for actors and organizations in each sector. ENGOs developed the novel practice of markets campaigning, and slowly scaled this up over a 20-year period until it has become institutionalized across a globally powerful cadre of ENGOs. Within the provincial political context, ENGOs used their marketplace power to bring companies directly into interest-based negotiations processes where they argued, deliberated and worked through their conflict to find mutually beneficial ways to protect forests. Here, actors in both sectors cultivated new practices for engaging with each other, building trust and shared visions, and developing and applying new knowledge to forest management and conservation. Models of sustainable forest management were in existence across Canada to act as prototypes, and ENGOs worked to promote these practices and make them desirable to adopt, through marketplace threats and promises. Targeted 'Fortune 1000' firms and the large brands in wood and paper markets developed new practices in the form of procurement policies, chain-of-custody research, and other corporate social responsibility practices. In several instances, senior corporate executives also met directly with government representatives in Canada to demand improved practices.

It is clear that these novel practices were central to advancing sustainability transitions. These niche practices are one part of a comprehensive strategy connected to cross-domain strategies the same civil society actors are pursuing to influence regimes, and strategies to shape and mobilize landscape-level consumer preference. As such, these spaces of novel practice are somewhat different from those socio-technical niches described in the MLP where new technology, user practices and regulatory structures can co-evolve and that emphasize protection from market forces and incumbent regulatory structures in order to succeed and scale (e.g. Geels and Schot, 2007; 2010). The bi-lateral negotiations processes may share some similarities with policy transition arenas, where policymakers design collaborative policy interventions by convening stakeholders to create new visions and rapid learning opportunities (e.g. Loorbach and Rotmans, 2010). However, in this case these niche practices were not driven by policy actors, but directly by civil society and firm actors. Overall, the case illustrates the breadth of niche practices that can emerge across domains as part of a multi-level transition, and how deliberate actions by civil society can cultivate such innovation niches framed not as spaces for the development and scaling of new technologies and their broader social structures, but for all kinds of novel practices, which could also be framed as social innovations (Westley and Antadze, 2010).

4.3 Landscape leverage and the role of social movements in co-structuring landscape trends

The final area this case contributes insight is regarding how actors orchestrating mutually reinforcing dynamics relate to the landscape level. Environmental movement actors in this case have influenced landscape-level cultural trends over the last 20 years, and strategically directed these pressures to destabilize and transform the incumbent forest products regime in Canada. Central to the ENGOs' strategies was mediating and co-constructing trends at the landscape level: selecting, strategically amplifying and directing emerging trends in consumer values and market preferences towards more sustainable purchasing. This was also done within the context of a long-term ecological trend of systematic degradation and loss of the world's original or frontier forests, which was made more salient to the regime through framing and communication strategies of ENGOs. To advance theorizing about the agency involved in orchestrating mutually reinforcing dynamics, we propose the concept of *landscape leverage* to describe the mechanisms of mediation and interpretation, where actors may deliberately mobilize and amplify landscape pressures onto the regime, or circumvent or render other landscape trends less powerful. Actors pursuing landscape leverage strategies could be seeking either to reinforce an incumbent regime or to disrupt it. The concept of landscape leverage is intended to clarify the agency involved in broad political and normative mobilization activities and their resultant influence on transition trajectories. Conceptualizing these disruptive, discursive, political activities as socio-technical niche practices conflates invention/innovation activities (and the associated shielding and nurturing they require) with political activities aimed at selectively amplifying and mobilizing particular landscape developments, in order to de-stabilize incumbent regimes.

The landscape is defined as the wider context influencing regimes and niches, and was recently clarified by Geels (2011) to be a derived concept – i.e. defined by what is "outside" the regime. Specifically, the landscape refers to the complex interrelated and continuously evolving "selection environment" consisting of societal values, macro-economic and ecological patterns, demographic trends and political ideologies – patterns which are more highly structured than those within regimes or niches (Giddens, 1984, Geels, 2011). Most importantly for our analysis, the landscape level is portrayed as exogenous, and outside the direct influence of actors in the short term (Geels, 2011, 28). In depictions of the MLP, the landscape is not influenced by niches, and is only influenced by regimes after they have been re-structured.

This framing of the landscape as exogenous to the influence of actors seeking sustainability transitions is problematic, and appears to have dissonance with Giddens' concept of structuration (1984) where agency and actor practices continuously co- structure processes even in highly institutionalized contexts. From an interpretive/constructivist perspective, regimes actors and organizations are continuously constructing the meaning of landscape trends, and such interpretation inevitably co-structures the landscape – i.e. some influences are more "real" than others (e.g. Carolan, 2004). Other landscape trends may have virtually no influence until meaning is made about them, or they change abruptly and force regime recognition due to shock. Diverse regime actors likely construct very different interpretations of the landscape's selection environment, depending on what trends they identify as being most salient in their specific domain. In the case of sustainability transitions, many important 'trends' in the landscape are also the cumulative negative social and ecological consequences that have been deliberately (or unintentionally) externalized by regime actors and firms in order to maximize financial return. Because the MLP is based on a constructivist and evolutionary ontology, it can accommodate a redefinition of the selection environment (landscape) as continually subject to re-structuration and re-interpretation by actors. This is particularly important for theorizing sustainability transitions, where it is the broader landscape trends – ecological, consumptive, values, and political ideologies – as well as the regimes themselves that must transform to achieve the normative goals of sustainability.

Geels (2010, 2011) acknowledges the special characteristics of complex sustainability transitions and underscores the increasing importance of social movements in advancing the discourse, socio-political framing, and debate necessary for such transitions. Grin et al. (2010) describe civil society as the context that shapes or articulates consumer preferences. This case illustrates how environmental actors strategically select and mobilize landscape pressures and bring them to bear on particular (more vulnerable or open) aspects of the regime. We have identified several mechanisms whereby actors interface with the landscape and bring influence to bear on the regime, through 1) selection, 2) framing, 3) amplifying, 4) mobilizing, and 5) translating.

Societal values are considered to be a landscape-level trend in the MLP, and the last decades have seen the emergence of consumer norms favouring ‘green’ products. As this case describes, for wood and paper products, the strategic agency of ENGOs actors through the pressure created by markets campaigns and FSC selected and framed latent consumer values – essentially turning them into “real” landscape pressures which were then deliberately brought to bear upon the regime. In order to do this, ENGOs **selected** the landscape-level cultural values of a sub-section of ethical consumers, large purchasers, and reputation-sensitive brands. Shifting markets for wood products actually meant that overall trends were towards less discerning consumers, however ENGOs deliberately cultivated European customers, targeted recognizable brands, and worked largely with grassroots (more green and radical) student groups to strategically select this sub-group with green values and give it a disproportionate influence within the landscape.

The sub-group was selected and activated through discursive strategies – **framing** or interpreting the problem of global deforestation and endangered species with compelling narratives and images, identifying ‘bad actors’ and clear actions to take. This frame was **amplified** by targeting globally recognizable brands such as Nike, Home Depot, Ikea, and Victoria’s Secret, using subversive media strategies, direct action, and other grassroots organizing and communications tactics. The targets were financially and materially linked to the forests being destroyed, which created turmoil, public relations challenges and ethical dilemmas for executives within the big brand companies being asked to boycott specific logging companies. These dilemmas took time and energy within senior executives of firms, and were further amplified by shareholder and investor concern. This conflict **mobilized** new emissaries such as corporate CEOs and the German publishing industry, who expressed their concerns directly to regime politicians, the Forest Products Association of Canada, and specific companies. A standing group of grassroots activists were also mobilized to redirect focus from one target to the next, sustaining the power of campaigns to shift purchasing choices in entire sectors.

Finally, through the impacts of mobilized emissaries, eroding corporate social license and political support, and direct financial costs due to cancelled contracts, the forest companies experienced sufficient risk and disruption to engage in a negotiated solutions-finding process. This regime opening had to then be **translated** by ENGOs into new, more sustainable institutional forms. Translation pressure came in the form of third-party forest certification and the improved practices demanded therein, from procurement policies from large buyers specifying new green product requirements, and from domestic political pressure generated through ENGO campaigns. Niche innovations defined and piloted in formal negotiations processes were taken up/translated by the regime at this time as well. Finally, once selected, framed, amplified, mobilized and translated, green consumer preferences continued to operate as a landscape pressure on the regime – implying that the campaign activity of ENGOs, coupled with changing norms and market dynamics, co-structured a new or more powerful landscape trend.

Lock-in and path dependency ensure that the selection environment favors ongoing maintenance of the regime, but this case shows how roving actors in the form of a well-organized global coalition of ENGOs were able to identify reasons for lock-in, and use creative (and even illegal) means to disrupt and then influence re-structuration of the regime. Regime actors may take regime functioning for granted, leaving them unprepared to defend it skillfully from de-stabilizing or de-legitimizing efforts from social movement actors. This kind of disruptive agency is distinct from that expressed within niches to generate socio-technical innovations, as it is specifically aimed at destabilizing the regime, and involves selecting and 'tapping into' landscape level trends in order to reconfigure regime rules and interpretations. Opportunities to enact disruptive agency are not available in equal measure to all regime (or niche) actors, due to various constraints on their behaviour. Highly embedded regime actors in any sector operate in environments structured by rules, norms, and accepted practices. For example, policy-makers are limited to taking action within their particular jurisdiction within existing policy constraints, and to playing politically-constrained roles in partnerships, learning networks and other informal mechanisms. Firm actors are limited by acting in ways that demonstrably increase shareholder and company value. Unlike other regime actors, civil society actors (in this case those working for ENGOS) do not have to expend energy maintaining the existing regime, meaning they are free to single-mindedly pursue the goal of regime transition to sustainability – using whatever cultural, political and economic strategies they can generate both inside and outside the regime. Civil society actors can both act directly to disrupt regime stability, and they can apply political or financial strategies to transform the limitations of other regime actors into opportunities for sustainability transitions (for example, increasing the cost to firms through boycott campaigns such that they must become open to sustainable practices, in order to maximize shareholder value). Because they can confer legitimacy, ENGOs can harness public opinion to enable wide support for government policy solutions, and enable firms to gain market access and secure social license.

ENGO actors generated new forms of power through wielding economic threats and by leveraging widespread consumer concern, but they also increased the salience and power of other firm stakeholders, specifically financiers, customers and shareholders who didn't want to be associated with targeted firms (Gritten, 2009). Their strategies both tapped into and shaped landscape level consumer preferences and values. The case suggests that that landscape level is more permeable to influence than depicted within the MLP, and that niche-to-landscape and mediated, agent-directed landscape-to-regime interactions may be as important to understanding sustainability transitions as niche-to-regime interactions. This deliberate agency involved in mediating landscape-level pressures illustrates an important role for actor networks in orchestrating mutually reinforcing dynamics, and opens up new theoretical avenues to understand the role of social movements in catalyzing sustainability transitions.

4.4 New patterns of agency and mutually reinforcing dynamics

In this paper, we were interested in the role of agency in mutual reinforcement of dynamics occurring between niche practices, incumbent regimes, and the landscape. Environmentalists working to protect Canada's forests and shift global markets enacted cross-domain strategies and worked across levels from landscape to niche – co-developing innovative niche practices, cultivating political and industry opportunity structures, and connecting influences at multiple levels in order to institutionalize new practices and policies. Table 1 summarizes an expanded matrix of mutually reinforcing dynamics – showing the cross-domain strategies used by ENGOs politically and in the marketplace across niche, regime and landscape levels. ENGOs pursued global strategies through markets campaigns and the creation of FSC because the domestic forestry regime was highly locked-in. By cultivating economic influence through threats of contract cancellations, both industry and government experienced elements of regime disruption. ENGOs also co-created transition dynamics by capitalizing on existing market and policy opportunity structures (shown in Table 1 at both regime and landscape levels). When advancing cross-domain strategies, the combination of creating new structures and co-opting existing ones in both markets and policy arenas enabled highly novel forest management practices to be institutionalized. The novel practices generated by ENGO campaigns were non-technical in nature, involving actors within forest companies, global corporations, ENGOs, consumers, grassroots activists, and governments and other policy actors. Finally, the table illustrates the marketplace and campaign strategies used by environmental actors to select, frame and amplify changing cultural values in the landscape, generating landscape leverage in the form of green consumer preference being brought to bear on the regime. This landscape trend was co-structured by environmental actors and continues to act as a landscape influence bearing down on forestry regimes.

Table 1. The Mutually Reinforcing Dynamics Orchestrated by ENGO Forest Campaigns

	ENGO Political Strategies	ENGO Market Strategies
Local niche *(novel practices)*	ENGOs frame and communicate possibility of different models; shift form conflict to bi-lateral negotiation; advance best practices; negotiate with industry to create new knowledge, principles, and pilot projects; jointly lobby for policy adoption	Call on large purchasers to implement procurement policies and supply chain management practices; shame bad actors, target representatives of key sectors; Create openings for alternative markets for fibre; praise early adopters
Regime *(New Institutions)*	Communicate, translate story of threats/win-win solutions to domestic public & decision-makers; grassroots and public campaigns; participate as stakeholders in provincial and national policy processes; partner with other power-holders, apply marketplace pressure to government to adopt new policies ***Political opportunity structures:*** New legislation to protect species, and provincial land use planning frameworks	Generate economic power through threat of contract cancellation; use market pressure to amplify political and discursive strategies; direct marketplace pressure onto elected officials through visiting delegations; co-develop new principles and agreements "win-win approaches" between ENGOs and industry; create FSC to define and drive adoption of sustainable forest management ***Industry opportunity structures:*** Forest sector readiness in Canada; FPAC leadership
Landscape leverage	Market campaigns against forest companies and global brands select green values, frame and amplify to speed adoption via procurement policies and economic threat; Hundreds of millions of dollars of contracts cancelled. Industry representatives visit Canadian politicians and demand change; global firm representatives act as political emissaries of green consumer values	Global ENGOs and local partners communicate story of threats/ solutions to marketplace, use grassroots big brand boycott campaigns, celebrities to frame/shape and translate green consumer values; FSC as mediating structure between landscape and regime – new global market regulations shaping landscape trends
Landscape	***Political Opportunity Structures*** Lack of effective global forest governance structures; social and consumer values in support of endangered forests, climate, and species; responsible business practices; win-win solutions, existing discourse on Canada as stewarding well-managed forests.	***Industry Opportunity Structures*** Greening consumer values; globalized forest products markets; pressure from demographic changes and loss of competitiveness; rise of interest in low-carbon forest products; FSC most widespread eco-certifier of paper, need for corporate social license.

Further Research

This paper identifies three conceptual gaps in the MLP and the governance approach to transitions that seem important to address in order to understand the dynamics of sustainability transitions. The role of civil society in Canadian forest sector transition illustrates a need for further development of the concept of cross-domain dynamics and the role of strategic agency in bridging across domains and levels. In this regard, both resilience approaches (e.g. Olsson et al., 2006; Westley et al. 2011) and social innovation literature (Westley and Antadze, 2010; Moore and Westley, 2009) could provide some useful concepts about cross-scale and cross-domain interactions, and the agency involved in navigating transitions. To build greater understanding of sustainability transitions pathways, there could be further theoretical synergies with social innovation literature because of its focus on non-technical innovation. The notion of opportunity structures may also be fruitful, and further research could analyze how these co-emerge with deliberate actor strategies, in markets, industries, policy arenas and culture. This paper provided some description of civil society's unique role in embodying a meta-perspective that can enable distributed competency for strategic agency, and their ability as roving, transition-focused actors to move more freely across levels and regime domains to identify leverage points to tip systems towards sustainability. More cases are needed to further describe strategies that civil society organizations can use to orchestrate mutually reinforcing dynamics, and to identify whether such strategic agency is unique to groups of global actors, or whether can be achieved through collaboration. This is particularly important for future research and practice to advance sustainability transitions, because these transitions are situated within the wider normative demands of sustainability and the 'meta-perspective' of global ecological limits. In this context, it seems urgent to continue to build a broader conceptualization of the agency involved in orchestrating mutually reinforcing dynamics, as the scope of society's sustainability challenges continues to grow. Related to this, the concept of landscape requires further elaboration as a conceptual category, in order to develop both its constructed nature, and to capture the dynamics of agency involved in mobilizing or directing landscape-level pressures onto regimes in support of sustainability transitions. Geels' (2011) recent reframing of the MLP as a flat ontology, not a nested hierarchy, may open up conceptual avenues to consider how niche and regime actors operate to co-construct and mediate landscape trends. In this sense, niches could be conceptualized as 'surrounding' regimes and interpreting/co-constructing and responding in innovative ways to landscape trends. Further constructivist-oriented development of the landscape within sustainability transitions may lead to the concept being reframed as both constructed and endogenous. Finally, we welcome challenge or further elaboration of our concept of 'landscape leverage' as a description of how niche actors can directly mediate between the landscape and regime levels within the MLP.

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Towards a comprehensive policy mix conceptualization: the case of renewable power generation technologies in Germany

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Abstract:

The required decarbonization of the energy system constitutes a formidable transition challenge with multiple market and system failures. Several studies have argued for the need to combine different policy instruments in so-called policy mixes for addressing these failures. However, some studies call for a more comprehensive policy mix concept to better reflect the complexity and dynamics of policy mixes. In this paper we take a first step towards such a comprehensive concept of the policy mix, taking the example of renewable power generation technologies in Germany whose increased development and diffusion is a prerequisite for the transition of the energy system. Given this research case we build our concept on a review of the literatures on environmental economics, innovation studies and policy analysis. The proposed concept, which accounts for the complex and dynamic nature of policy mixes, consists of the three building blocks *elements*, *processes* and *dimensions;* elements are characterized by the term *consistency*, processes by the term *coherence*. We argue that this more comprehensive policy mix concept with its uniform terminology does not only account for the complex and dynamic nature of policy mixes but also provides an interdisciplinary analytical framework for application in empirical studies. Based on this concept we derive policy implications and suggest avenues of future empirical and conceptual research.

Keywords:

policy mix, policy strategy, instrument mix, policy making and implementation, consistency, coherence

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1 Introduction

Addressing the climate change challenge requires decarbonizing the economy. However, such a transition is faced with multiple market, system and institutional failures and thus requires multi-faceted policy intervention (Lehmann, 2010; Twomey, 2012; Weber and Rohracher, 2012). In recent years, this need has been captured by calling for a climate policy mix which combines several policy instruments (IEA, 2011b; Matthes, 2010b). Similarly, the term policy mix has also been increasingly used in the context of environmental policy (OECD, 2007; Ring and Schröter-Schlaack, 2011) and innovation policy (Flanagan et al., 2011; Nauwelaers et al., 2009). However, policy mix studies tend to exhibit a limited scope, often either focusing on instrument interactions (e.g. del Río González, 2006; IEA, 2011a) or the policy processes associated with designing policy mixes (Howlett and Rayner, 2007). Also, the terminology applied in these studies is often ambiguous, particularly regarding the desired characteristics of a policy mix.[3]

This limited scope and ambiguous terminology of existing policy mix studies have two major consequences. First, due to the narrow scope of policy mix concepts researchers may neglect important policy mix elements or processes in their analyses. This may lead to an insufficient understanding of the complex nature of policy mixes and their effects, potentially resulting in fragmentary and oversimplified policy recommendations. Second, the lack of a uniform terminology may render policy mix analyses difficult to assess, compare and synthesize. As a result, policy mix studies may suggest ambiguous findings, ultimately reducing the substance and impact of their policy recommendations.

In this study we address the identified lack of a comprehensive, uniformly defined policy mix concept, thereby following Flanagan et al. (2011) and their call for a reconceptualization of the policy mix. More precisely, we aim at identifying and defining the key elements and processes of a policy mix and how they can be characterized, and in doing so also consider overarching dimensions. Our ultimate objective is to take a first step towards the development of a uniform and comprehensive policy mix conceptualization serving as starting point and integrating

3 For instance, given the limitations of the EU emission trading system Matthes (2010b) (p.6) calls for a "comprehensive, effective, economically efficient, robust, politically achievable, and inclusive climate policy mix". Regarding climate innovations in the power sector Schmidt et al. (2012a) (p.476) stress the need for a "consistent and effective policy mix which is congruent to long-term targets. Likewise, OECD (2007) (p. 22) recommends an increase of "the coherence of the instrument mix" for environmental policy and Nauwelaers et al. (2009) (p.11) underline the "need for coherence, coordination, and effectiveness of policy mixes" for R&D.

framework for empirical analyses. Such an analytical framework should enhance our understanding of policy mix outcomes and impacts and thus ultimately enable more precise policy recommendations.

Given the intended empirical applicability of the concept, we chose the research case of renewable power generation technologies (RPGTs) whose accelerated development and diffusion is a major prerequisite for the transition to a decarbonized energy system. Such a transition represents one of the key challenges humankind faces in the light of global climate change (IPCC, 2007) and is a prime example for the need of a policy mix. Our research case requires the review of the relevant literature in the fields of environmental economics, innovation studies and policy analysis. In addition, where needed, we complement our literature survey with contributions from other fields, such as strategic management. In this paper, we make a first attempt at integrating the various conceptions and definitions from these diverse and often still largely separated literatures into a comprehensive, interdisciplinary policy mix concept, which may also serve as starting point for other research cases.

The remainder of the paper is structured as follows: In section 2 we review the literature on policy mixes and their characteristics and derive requirements for a more comprehensive policy mix concept. Based on this, in section 3 we present the three building blocks of the proposed policy mix concept - elements (section 3.1), processes (section 3.2) and dimensions (section 3.3) – and synthesize these in section 3.4. Finally, in section 4 we discuss this proposed analytical framework and derive policy implications. Section 5 concludes the paper.

2 Literature review

2.1 Policy mix

A growing number of studies in different scientific fields uses the term "policy mix", e.g. Lehmann (2010) in environmental economics, Nauwelaers et al. (2009) and de Heide (2011) in innovation studies, and Howlett and Rayner (2007) in the field of policy analysis. [4] In its most basic form, studies implicitly or explicitly define a "policy mix" as the combination of several policy instruments (e.g. Lehmann 2012, Matthes 2010). [5] However, as stressed by Flanagan et al. (2011), a policy mix is more than a combination of policy instruments as it is shaped by several factors, namely actors, instruments, institutions and interactions. As a consequence, studies focusing on the combination of instruments only should, more precisely, refer to the term "instrument mix" (see section 3.1.3), as done, for example, by OECD (2007), Braathen (2007) or Murphy et al. (2012).[6] Table 1 shows an overview of some "policy mix" definitions, with the more elaborate ones mainly originating from innovation studies and the policy analysis literature.

Table 1: Definitions of the term "policy mix" in the literature

Source	Definition
Guy et al. (2009) (p.1)	"An R&D and Innovation Policy Mix can be defined as that set of government policies which, by design or fortune, has direct or indirect impacts on the development of an R&D and innovation system."
Kern and Howlett (2009) (p.395)	"Policy mixes are complex arrangements of multiple goals and means which, in many cases, have developed incrementally over many years."
Nauwelaers et al. (2009) (p.3)	"A policy mix is defined as: The combination of policy in-

4 A review of the origins of the term in economic policy and its subsequent uptake in the fields of environmental and later also innovation policy can be found in Flanagan et al. (2011).

5 Some studies also use the term "policy mix" interchangeably with "instrument mix" (e.g. Ring, Schröter-Schlaack (2011)).

6 Similarly, Borrás and Edquist (2013) argue for a distinction between instrument mix vs. policy mix (see footnote 6, p. 6).

	struments, which interact to influence the quantity and quality of R&D investments in public and private sectors.”
Boekholt (2010) (p.353)	“A policy mix can be defined as the combination of policy instruments, which interact to influence the quantity and quality of R&D investments in public and private sectors.”
De Heide (2011) (p.2)	“A policy mix is the combined set of interacting policy instruments of a country addressing R&D and innovation.”
Ring and Schröter-Schlaack (2011) (p.15)	“A policy mix is a combination of policy instruments which has evolved to influence the quantity and quality of biodiversity conservation and ecosystem service provision in public and private sectors.”

Three general features emerge from these definitions: First, they typically include the ultimate *objective(s)* of the policy mix, either in an abstract form (Kern and Howlett, 2009) but more typically as a specific objective of a certain policy field, such as innovation (Boekholt, 2010; Guy et al., 2009; Nauwelaers et al., 2009) or biodiversity policy (Ring and Schröter-Schlaack, 2011). Second, *interaction* is a central feature of the existing policy mix definitions (Boekholt, 2010; de Heide, 2011; Nauwelaers et al., 2009). It has been studied most extensively in the climate and energy field, where the focus is often on its influence on the effectiveness and efficiency of instruments in the mix (2009a; del Río González, 2010; IEA, 2011b; Sorrell et al., 2003). Third, some of the definitions point to the *dynamic nature* of the policy mix (also see Flanagan et al. (2011)), referring to it as having “evolved” (Ring and Schröter-Schlaack, 2011) and “developed incrementally over many years” (Kern and Howlett, 2009). This reflects that instruments and their meanings can change over time and based on this, interactions between such instruments change (IEA, 2011b; Sorrell et al., 2003).

Yet, a comprehensive policy mix concept needs to go beyond these general features - interacting instruments aimed at achieving objectives in a dynamic setting – at least in three regards. First, aside from capturing its dynamic nature a comprehensive concept of the policy mix also should consider its *complexity*, thereby exceeding the consideration of only a combination of policy instruments and their interactions (Flanagan et al., 2011). Second, it needs to incorporate *policy processes* “by which policies emerge, interact and have effects” (Flanagan et al. (2011), p.702) since such processes help explain the evolution and effects of policy mixes, as discussed, for example, by Foxon and Pearson (2007; 2008) for the case of innovation in renewable power generation technologies. Third, a comprehensive policy mix concept ought to include a *strategic* *component*. This tends to be neglected despite early works of Jänicke on the role of strategic approaches in environmental policy (Jänicke, 1998; Jänicke, 2009) and recent empirical evidence on the importance of long-term climate targets for companies' innovation strategies (Rogge et al. (2011a; 2011b), Schmidt et al. (2012b)).

2.2 Characteristics of policy mixes

The literature uses a number of terms for describing the desired nature of a policy mix and its effects. These can be classified in two main groups: policy mix characteristics and assessment criteria (OECD/PUMA, 2003; Sorrell et al., 2003). Terms belonging to the latter group represent well established ex-ante and ex-post assessment criteria applied in impact assessments and policy evaluations of single instruments, such as effectiveness, efficiency, equity or feasibility (del Rio et al., 2012; IRENA, 2012). In contrast, the former group consists of terms specifically used for characterizing the policy mix, such as consistency, coherence, comprehensiveness or congruence (Howlett and Rayner, 2007; Kern and Howlett, 2009; Matthes, 2010a). These often ambiguously defined characteristics may impact the performance of a policy mix in terms of the standard assessment criteria, particularly regarding effectiveness and (dynamic) efficiency. However, most policy mix studies refer to these characteristics without clarifying which of the various definitions they are applying, thus rendering it difficult to assess what is actually meant. Therefore, we review the literature on two of the most frequently used but heterogeneously defined characteristics of policy mixes: consistency and coherence (Den Hertog and Stroß, 2011; Picciotto, 2005).[7] Based on the diversity of meanings found in the – predominantly policy analysis – literature we identify three important points to be taken into account when establishing a more uniform terminology.

First, consistency and coherence are either seen as *identical or different characteristics*. The former suggests coherence is synonymous with consistency (e.g. Carbone, 2008; Hoebink, 2004; Matthews, 2011). As a result, coherence is often simply defined using the term consisten-

7 For an overview of definitions of consistency and coherence see Table 14 in the annex. Weston and Pierre-Antoine (Weston and Pierre-Antoine, 2003) provide a historical account of the relevance of policy coherence for development policies.

cy (e.g. Hydén, 1999; Picciotto et al., 2004), but there is no uniform definition. [8] In contrast, the latter distinguishes consistency and coherence as different characteristics (e.g. Howlett and Rayner, 2007; Mickwitz et al., 2009a; OECD, 2001), but again there is no agreement on the exact nature of this difference. However, the majority of these studies propose that coherence is greater than consistency (e.g. Jones, 2002; OECD/PUMA, 2003). That is, in its most basic form, consistency is seen as absence of contradictions (e.g. Den Hertog and Stroß, 2011; Gauttier, 2004), while coherence is defined to go further than this by calling for an achievement of synergy or positive connections (e.g. Missiroli, 2001; Tietje, 1997).[9].

Second, the literature differentiates between a *state and process perspective* of consistency and coherence, i.e. between what is being achieved and how it is achieved (e.g. Carbone, 2008), but again this is not treated uniformly. A first set of studies addresses the state of affairs at a certain point in time only (e.g. Duraiappah and Bhardwaj, 2007; Fukasaku and Hirata, 1995; Hoebink, 2004). A second set instead captures the process perspective (e.g. Jones, 2002; Lockhart, 2005; OECD/PUMA, 2003), thus concentrating on the organizational set up to attain consistency / coherence. A third set of studies mentions - either implicitly or explicitly – both state and process perspectives, but uses the same term – typically coherence – for both (e.g. Den Hertog and Stroß, 2011; Forster and Stokke, 1999; McLean Hilker, 2004), rendering it difficult to differentiate between the two.

Third, another key point is the focus on *tools* for enhancing consistency and coherence (e.g. Ashoff, 2005; OECD, 1996; OECD/PUMA, 2003), a discussion which is closely linked to the literature on policy coordination [10] and integration [11] (Mickwitz et al., 2009a; Van Bommel and

8 While some base their definition on the absence of contradictions and non-conflicting signals (e.g. Forster and Stokke, 1999; Van Bommel and Kuindersma, 2008), others refer to the consistency or coherence among policies (e.g. Bigsten, 2007; Di Francesco, 2001; OECD, 1996), while yet others speak of consistency or coherence between objectives and instruments (e.g. Fukasaku and Hirata, 1995; Picciotto, 2005).

9 An alternative view was developed by Howlett et al. who speak of consistency of instruments and coherence of goals (Howlett and Rayner, 2007) and also introduce congruence among instruments and goals as third category (Kern and Howlett, 2009).

10 Policy coordination is a formal policy process aiming to “getting the various institutional and managerial systems, which formulate policy, to work together” (OECD/PUMA, 2003, p. 9). Subsets of policy coordination are cooperation and collaboration (Bouckaert et al., 2010).

Kuindersma, 2008). However, as before, there is no common understanding of the terms consistency and coherence, and how they relate to other concepts, such as coordination. One reason for this lack of a uniform terminology may be the often largely separated contributions addressing distinct policy fields, such as development policy (e.g. EU, 2005; 2010), climate policy (Kern and Howlett, 2009; Mickwitz et al., 2009b) and eco-innovation policy (e.g. Reid and Miedzinski, 2008; Ruud and Larsen, 2004).

As a consequence of such diversity in meaning and the resulting difficulties of integrating findings across studies, a comprehensive policy mix concept needs to propose uniform definitions of these terms fulfilling the following two requirements. First, these definitions need to clearly specify whether they refer to the state or process perspective of the policy mix, which might best be accomplished by separate terms for each of these perspectives. Second, they should allow for the differentiation of a weak and strong form to capture the distinction between just the absence of contradictions and actual synergies within a policy mix. Ultimately, such a uniform terminology within a comprehensive policy mix concept would pave the way for a fruitful exchange of currently still largely disconnected research efforts.

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11 Environmental policy integration means “the incorporation of environmental objectives into all stages of policy making in non-environmental policy sectors [...] accompanied by an attempt to aggregate presumed environmental consequences into an overall evaluation of policy, and a commitment to minimize contradictions between environmental and sectoral policies” (Lafferty and Hovden, 2003), p. 9.

3 Building blocks of a comprehensive policy mix concept

As derived in the literature review a more comprehensive policy mix concept needs to address four basic requirements: (i) the consideration of the complex and dynamic nature of policy mixes, (ii) the incorporation of associated policy processes, (iii) the inclusion of a strategic component, and (iv) the precise definition of key terms. Based on these requirements we define the policy mix as a combination of a policy strategy and interacting policy instruments, i.e. the instrument mix, which, intentionally or unintentionally, influence, together with policy making and implementation, the achievement of policy objectives, and whose complex and dynamic nature is illustrated by its dimensions. In the following, we introduce the associated three building blocks of the proposed policy mix concept: elements (see section 3.1), processes (see section 3.2) and dimensions (see section 3.3).

3.1 Elements

3.1.1 Policy strategy

Since the importance of a long-term strategic orientation and strategic policy frameworks has been increasingly pointed out by the literature addressing sustainability challenges (Foxon and Pearson, 2008; Quitzow, 2011; Weber and Rohracher, 2012) and innovation effects of climate policies (Rogge et al., 2011b; Schmidt et al., 2012b), we incorporate policy strategy as one of the elements in the comprehensive policy mix concept. However, given its conceptual underdevelopment, we draw on the strategic management literature to derive a common definition of policy strategy (see Table 2 in the annex). This literature highlights that strategy consists of a combination of interdependent ends (goals) and means (policies) to achieve the ends (Andrews, 1987; Miles and Snow, 1978; Mintzberg, 1999; Porter, 1980).

Building on Andrews (1987) and Porter (1980) we thus define policy strategy as combination of policy objectives and the principal plans for achieving these. That is, the definition puts an emphasis on the output of the strategy process – the ends and means – rather than the process of formulating and implementing objectives and plans (see section 3.2.1). We will discuss these two main components in turn, albeit recognizing that they are closely linked with each other.

The first component of the policy strategy definition concerns *policy objectives*. These tend to be substantiated with (typically long-term) *targets* (Rennings et al., 2003; Schmidt et al., 2012b) and may be based on visions of the future (del Río et al., 2010; Kemp and Rotmans, 2005).[12] [13] For example, one of the policy objectives of the EU is the reduction of greenhouse gas (GHG) emissions. This is concretized by a 20% GHG reduction target for 2020 compared to 1990, with negotiations underway for updating this to 2030, aiming at arriving at numbers in line with the internationally agreed target of 2°C (EU, 2013). [14] In addition to environmental objectives, the policy strategy may also include social and economic issues (Daly and Farley, 2010), such as the support of growth, competitiveness and jobs (EU, 2013). Besides content-oriented objectives, a policy strategy can also contain process and learning objectives, which may be particularly relevant in the context of transition management (Kemp, 2007; Rotmans et al., 2001). Finally, policy objectives and particularly their corresponding targets can be characterized by their *credibility* (e.g. Gilardi, 2002). This credibility may be influenced by a range of factors, such as the targets' binding character, the commitment from political leadership, the operationalization by effective instruments, the delegation of competencies to independent agencies, and the policy style (see section 3.2.1).

The second component of the strategy definition addresses the *principal plans* for achieving these objectives. Such plans outline the general path that governments propose to take for the attainment of their objectives and include framework conventions, guidelines, strategic action plans and roadmaps. In communicating not only the ends but also the means to achieve these the policy strategy gives direction to actions and decisions (Grant, 2005). An example for principal plans at the EU level is the Strategic Energy Technology (SET) Plan, while at a German national level the Renewable Energy Action Plan, the German Energy Concept and the 6th Energy Research Program provide key examples.

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12 In this distinction between objectives and targets we follow Tuominen and Himanen (2007, p. 390) who define a policy objective as "What the policy is trying to achieve, the overall goal; often quite abstract and qualitative" and a policy target as "More specific and quantitative than an objective [..] (e.g. 10% less emissions of air pollutants within 5 years). The target points out a clear sense of direction for policy measures."

13 Targets can be characterized by a number of factors, including their type (e.g. specific, absolute), their governance level (e.g. EU, national), their scope (e.g. headline target, sub-target), their time horizon (e.g. long-term, interim) or their legal nature (e.g. binding, aspirational, voluntary), see e.g. EU (2013) and Philibert and Pershing (20xx).

14 This target [20% GHG reduction until 2020 compared to 1990] is one of the three EU headline targets (20-20-20 targets) which also include a 20% share for renewable energy sources in the energy consumed in the EU (EU, 2008a) and 20% savings in energy consumption compared to projections for 2020 (EU, 2008b).

The long-term perspective inherent in the policy strategy (Hillman and Hitt, 1999) can play a fundamental role in providing actors with the needed guidance of the search and thus contribute to one of the functions of innovation systems (Hekkert et al., 2007). For example, research has shown the vital role of long-term climate targets for R&D activities of companies in the power sector (Rogge et al., 2011a; 2011b; Schmidt et al., 2012b). However, the same research has also pointed out that this strategic element of the policy mix on its own is not sufficient for changing companies' innovation strategies but needs to be operationalized by concrete policy instruments. These will be addressed in the next section.

3.1.2 Instruments

Policy instruments constitute the concrete tools to achieve overarching objectives. More precisely, they can be seen as tools (Salamon, 2002) or techniques of governance (Howlett, 2005) that address policy problems (Pal, 2006) and come about with the active involvement of the public sector (Nauwelaers et al., 2009) or, more specifically, are introduced by a governing body (Sorrell et al., 2003) in order to achieve policy objectives (Howlett and Rayner, 2007), thereby translating plans of action (de Heide, 2011). [15] Examples for policy instruments within the policy mix for renewables include the German Renewable Energy Act (EEG), the KfW Program Renewable Energies, the EU ETS and the European Energy Program for Recovery (EEPR).

As such, policy instruments are typically associated with specific *goals*. [16] That is, while the policy strategy contains objectives which tend to be specified by (long-term) targets, we denote the term "goal" for characterizing the intended effect of instruments, which contribute to achieving overarching policy objectives.

Studies on policy instruments do not only use the term instrument, but also speak of implementing measures (e.g. EU, 2013), programs (e.g. Komor and Bazilian, 2005), policies (e.g. Fischer and Preonas, 2010; IRENA, 2012), or policies and measures (e.g. UNFCC 2011). For simplicity reasons, we use the term "instruments" in the policy mix concept, with a clear understanding

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15 For further definitions of policy instruments see Table 9 in the annex.

16 Some authors refer to such an association of instruments and goals as "policy" (May, 2003; Pal, 2006).

that it comprises these alternative terms. However, as the term "policy" is very broad [17] we prefer not to use it as synonym for "instrument".

In the following, we discuss two key characteristics of policy instruments with particular relevance for innovation (e.g. Kemp, 2007; Rennings et al., 2008), namely instrument types (section 3.1.2.1) and instrument design features (section 3.1.2.2).

3.1.2.1 Instrument type

The type of an instrument has been identified as a major determinant of the innovation impact of environmental policy instruments, both in theoretical (Jaffe et al., 2002; Popp et al., 2009; Requate, 2005) and empirical studies in environmental economics (Hašcic et al., 2009; Hemmelskamp, 1999; Johnstone et al., 2010). Since challenges such as the transition of the energy system towards renewables require a systemic view, the policy mix concept needs to incorporate instrument types not only from environmental but also innovation policy. However, no uniform instrument typology exists in either policy field (e.g. Hufnagl, 2010). [18] Also, first attempts for a combined typology (see Table 10 in the annex) tend to either lack a differentiated set of innovation policy types (Rennings et al., 2008)[19] or environmental policy types (Nauwelaers et al., 2009), depending on their disciplinary focus.

Therefore, what is needed is a typology of policy instruments combining types from both fields in a more balanced manner. As a first step towards such a typology we identified frequent typologies in the environmental and innovation domain (see Table 2). While in the environmental domain both simple and differentiated typology are rather well established instrument classifications, for the innovation domain this is only the case for the simple typology of technology push vs. demand pull. Since more differentiated innovation policy typologies vary greatly (Hufnagl, 2010), we condensed them to some recurring basic instrument types.

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17 For example, Dye (2008, p. 1) defines public policy as "whatever governments choose to do or not to do [..] public policies may regulate behavior, organize bureaucracies, distribute benefits, or extract taxes – or all these things at once."

18 For an overview of key instrument type classifications within the scientific disciplines of environmental economics, innovation studies and policy analysis, see Table 15 in the annex.

19 One exception being del Río (2009b).

Table 2: Frequent typologies in the environmental and innovation policy domain

	Simple typology	Differentiated typology
environmental domain	• market-/ price-based / economic • regulation / command-and-control	• market-/ price-based / economic • regulation / command-and-control • information & education • voluntary approaches
innovation domain	• supply-side measures/ technology push • demand-side measures/ demand pull	• financial support • public procurement • stimulation of cooperation and networks • provision of public goods • provision of property rights • systemic instruments

Source: Own compilation based on typologies by (Dasgupta and Maskin, 1987; Gunningham and Young, 1997; Hemmelskamp, 1999; IEA, 2011b; Jordan et al., 2003; Rammer, 2009; Smits and Kuhlmann, 2004; Sorrell et al., 2003; Sterner, 2000; Taylor, 2008; Wieczorek and Hekkert, 2012)

Based on these generic typologies we propose a matrix typology (see Table 3) that combines three instrument types (inspired by the environmental domain) with three instrument purposes (inspired by the innovation domain). More specifically, the three instrument types are economic instruments, regulation and information, with the latter one including education and cooperation. The primary instrument purposes differentiate between technology push, demand pull and systemic. Despite this distinction ultimately it is the resulting instrument mix which needs to cover all three purposes, particularly when it comes to social challenges, such as the transition to a decarbonized energy system (Foray et al., 2012; Schmidt et al., 2012b). Since this 3x3 matrix is an oversimplification of reality, and as such is not free from overlaps [20] we qualify both instrument purpose and type with the word "primary". For each of the nine possible type-purpose-combinations Table 3 includes some selected examples of instruments relevant for renewables.

Table 3: Type-purpose instrument typology *(with selected instrument examples)*

PRIMARY TYPE \ PRIMARY PURPOSE	technology push	demand pull	systemic
Economic instruments	*RD&D grants and loans*, tax incentives, state equity assistance*	*subsidies, trading systems, taxes, levies, deposit-refund-systems, public procurement, export credit guarantees*	*tax and subsidy reforms, infrastructure provision*
Regulation	*patent law, intellectual property rights*	*technology / performance standards, prohibition of products / practices, application constraints*	*market design, environmental liability law*
Information	*professional training and qualification, entrepreneurship training, scientific workshops*	*training on new technologies, rating and labelling programs, public information campaigns*	*education system, thematic meetings, public debates, cooperative RD&D* programs, clusters*

Source: Own elaboration (based on del Río González, 2009a; Edler and Georghiou, 2007; Hemmelskamp, 1999; IEA, 2011b; Mowery, 1995; Rammer, 2009; Rennings et al., 2008; Smits and Kuhlmann, 2004; Sterner, 2000; Wieczorek and Hekkert, 2012)

3.1.2.2 Instrument design features

In the literature it has been increasingly pointed out that a policy instrument's design features may be actually more influential for innovation than the instrument type (e.g. Kemp and Pontoglio, 2011; Vollebergh, 2007). Therefore, a rising number of studies are explicitly considering them when analyzing policy instruments and their innovation effects (e.g. Ashford et al., 1985; Blazejczak et al., 1999; Norberg-Bohm, 1999). Design features can be differentiated in rather abstract and rather descriptive features. However, many studies focus on abstract features (see

20 For example, a trading system, such as the EU ETS, is primarily viewed as demand-pull instrument, but the change in relative prices not only affects diffusion but also innovation (Jaffe et al., 2002), so that one could argue to classify it as economic instrument serving a system wide purpose. However, empirical evidence backs the primary effect occurring on the adoption of technologies, not on RD&D (Rogge et al., 2011b; Schmidt et al., 2012b), thus pointing to the meaningfulness of classifying trading schemes as economic instruments primarily serving demand pull purposes.

Table 13 in the annex), such as stringency or flexibility (e.g. Hašcic et al., 2009; Kemp and Pontoglio, 2011; Kivimaa, 2007). [21] Yet, descriptive design features summarizing the legal form [22] and the content of a policy instrument, such as those used by del Río (2012) for feed-in tariffs (see Table 6), can be a first step in identifying how a policy instrument performs regarding selected abstract design features.

A number of abstract design features have been proposed in the literature (e.g. Hašcic et al., 2009; Kemp and Pontoglio, 2011), but there is no uniformly agreed list. However, considering the requirements of our research case we propose stringency, profitability, predictability, flexibility, differentiation and depth as abstract instrument design features with the highest relevance regarding the impact of policy instruments on innovation.

First, *stringency* addresses the ambition level of an instrument both in terms of its goal and its design, with the individually perceived stringency being ultimately determined by the characteristics of the instrument's target actors, such as its technology portfolio (Rogge, 2010). [23] Even though definitions and operationalizations of stringency vary among studies [24] findings point to a positive impact of stringency on innovation (e.g. Ashford et al., 1985; Frondel et al., 2007; 2008; Kammerer, 2008; Rogge et al., 2011b; 2011c; Schmidt et al., 2012b; Yarime, 2007).

Second, we introduce *profitability* as abstract design feature to capture an instrument's effect on the return of an investment. A prime example is the level of feed-in tariffs and its effect on the return of investments in renewable power generation technologies, where higher tariffs imply greater profitability. Typically, instruments classified as "carrots", such as subsidies, would

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[21] Not all of the abstract design features found in the literature concern instruments only, but also include aspects relevant for policy making and implementation, such as continuous improvement (Kivimaa and Mickwitz, 2006) and enforcement (Kemp, 1997), as well as for the policy strategy, such as credibility (Kemp and Pontoglio, 2011).

[22] This legal form determines, for example, the binding character of an instrument, which can range from voluntary agreements to compulsory measures.

[23] For example, in the EU ETS the cap sets the limit to overall emissions with straightforward repercussions for the price of allowances. In addition, the mode of allocating allowances also contributes to the firm-level stringency of the trading scheme depending on a firm's technology portfolio and thus its exposure to the instrument (Rogge, 2010).

[24] Definitions range from a focus on the ambitiousness of the instrument goal relative to the baseline trajectory (e.g. Hašcic et al., 2009) to a concentration on firm-level necessary monetary efforts for complying with the requirements of a policy instrument (e.g. Bernauer et al., 2006).

have a positive effect on profitability and thus investments, although thresholds may have to be surpassed which may vary among target actors.

Third, *predictability*, having gained attention particularly in relation to the EU ETS and a post-Kyoto international climate agreement (Engau and Hoffmann, 2009; Hoffmann et al., 2008), „captures the degree of certainty associated with a policy instrument and its future development. This concerns the instrument's overall direction, detailed rules, and timing“ (Rogge et al., 2011b, p. 515). As such it ultimately addresses the effect of a policy instrument on investor uncertainty (Hašcic et al., 2009). Empirical studies on the EU ETS and the power sector suggest that predictability may matter most for RD&D decisions, possibly due to the sector’s long-lived capital-intensive investments (Rogge et al., 2011b).

Fourth, *flexibility* captures the extent to which innovators are allowed to freely choose their preferred way of achieving compliance with an instrument (e.g. Kivimaa and Mickwitz, 2006; Norberg-Bohm, 1999). For example, Johnstone and Hašcic (2009) find that for “a given level of policy stringency, countries with more flexible environmental policies are more likely to generate innovations which are diffused widely and are more likely to benefit from innovations generated elsewhere” (Johnstone and Hašcic, 2009, p. 1).

A fifth abstract design feature concerns the *differentiation* specified in policy instruments (Kemp and Pontoglio, 2011), e.g. with regard to industrial sector, size of the plant or geographical location. Finally, the *depth* of a policy instrument addresses the range of its innovation incentives, meaning whether it delivers incentives all the way down to potential solutions with zero emissions (Hašcic et al., 2009).

An instrument’s design features do not only determine its innovation incentives but may also impact its effectiveness and efficiency and are a prerequisite for interaction analyses (e.g. del Río González, 2009a). Given their importance, we illustrate the design features for the example of the German Renewable Energy Act (EEG), the core instrument in the German policy mix for renewables. As a first step, we apply del Rio’s (2012) list of descriptive design features to the EEG (see Table 4), which then may serve as basis for determining the performance of the EEG in terms of the abstract design features. For example, due to the 20 years of support the predictability of the EEG can be estimated to be high. Another example would be the flexibility of the current EEG for investors, which has increased compared to previous versions as they can now choose between a fixed tariff and the market premium model.

Table 4: Specific design features of the German EEG (2012)

design feature	materialization
type of FIT	fixed tariff OR market premium model
support tied to electricity price	only for market premium
technology-specific FITs	yes (hydro, landfill gas, sewage gas, firedamp, biomass, geothermal, wind onshore/ offshore, solar power)
cap/ floor price	no; for market premium corridor depending on market price
degression	yes, technology-specific; partly also geography- and size-specific
reduction of support for existing plants	no
duration of support	20 years
support paid by whom	electricity consumers
maximum size of plants	yes, except for wind power
capacity limit per technology	no, except for PV

Source: Own compilation based on features presented in del Rio (2012)

Finally, the interwoven nature of design features requires them to be balanced with each other (Kemp, 2007). For example, empirical studies recommend a gradual tightening of the stringency in a predictable manner, at the same time providing enough flexibility to allow for the exploration of new technological developments (Kivimaa, 2007).

3.1.3 Instrument mix

Moving from single instruments to their combination brings us to the instrument mix, which we conceptualize as being only a part of the overarching policy mix, thus calling for a distinction between both terms. It may be useful to distinguish between core (or cornerstone) instruments and complementary (or supplementary) instruments of a mix (IEA, 2011b; Matthes, 2010a; Schmidt et al., 2012b). Taking the example of the instrument mix for renewables in Germany, the core instrument would be the EEG with its feed-in tariffs, which is complemented by other instruments such as the KfW offshore wind program.

The instrument mix is characterized by the interactions between the instruments, which signify "that the influence of one policy instrument is modified by the co-existence of other [instruments]" (Nauwelaers et al., 2009, p.4). This influence originates from the effect that the operation of one instrument has on the operation or outcomes of another one, e.g. either directly or indirectly (Oikonomou and Jepma, 2008; Sorrell et al., 2003). Clearly, these interdependencies of instruments largely influence the combined effect of the instrument mix and thus the achievement of policy objectives (Flanagan et al., 2011). It is for this reason that interactions of policy instruments constitute a central characteristic of any policy mix concept.

Understanding the mechanisms and consequences of policy interactions requires the consideration of a number of aspects, including the scope of the interacting instruments, the nature of their goals, their timing, operation and implementation processes (Sorrell et al., 2003), suggesting that interaction outcomes are not only determined by the instrument mix but also shaped by the overarching policy mix. Naturally, the desired outcome is a positive or complementary effect, an example being the interaction of education & information as well as financial instruments with most other instrument types (Sorrell et al., 2003). Yet, perhaps more often negative or incompatible outcomes can be observed, such as technology standards frequently leading to negative interactions with other instrument types (Gunningham and Grabosky, 1998; Sorrell et al., 2003). However, as already pointed out by Gunningham and Grabosky (1998), assessing interaction outcomes without considering the particular context in which they occur can only be tentative, thus calling for empirical analyses.

So far, interactions have been predominantly dealt with in the environmental domain, particularly on climate and energy issues (del Río González, 2009a; Gunningham and Grabosky, 1998; Sorrell et al., 2003). More recently, innovation studies have also started to study interactions (Flanagan et al., 2011; Nauwelaers et al., 2009). All of these studies recognize the importance of instrument interactions as central aspect when dealing with policy mixes as well as the need to avoid negative interactions. In contrast, the policy analysis literature does not usually employ the term interaction but instead refers to consistency and coherence when addressing the interrelationships between different instruments, a point we take up in the next section.

3.1.4 Consistency of elements

Building upon the literature review in section 2.2, we propose to characterize the elements of the policy mix with the term consistency. That is, we suggest that consistency refers to the state of a policy mix that is characterized, in its weak form, by the absence of contradictions and, in its strong form, by the existence of synergies within and between the elements of the policy mix, thereby enabling the achievement of policy objectives. As such, the consistency of the policy mix encompasses three levels: (1) consistency of the policy strategy, (2) consistency of the instrument mix as determined by the nature of its interactions, and (3) consistency of the instrument mix with the policy strategy.

We highlight three key features of this consistency definition. First, it focuses on the state of the elements of the policy mix at any given point in time, i.e. we explicitly exclude the process perspective (for this, see section 3.2.2 on coherence). Of course, the consistency of the policy mix can be captured dynamically by measuring it over time (see section 3.3 on dimensions). Second, we differentiate between weak and strong consistency. By weak consistency we mean that at a minimum, a consistent policy mix needs to be free of contradictions or conflicts within or between its elements (Forster and Stokke, 1999) so that these do not - deliberately or accidentally - impair the achievement of policy mix objectives (Ashoff, 2005; Hoebink, 2004; McLean Hilker, 2004). In contrast, strong consistency refers to complementarities, mutual support and synergies between and within the elements of the policy mix. Third, we envisage three main levels of policy mix consistency, which we discuss in the subsequent paragraphs.

We chose the *first level* of policy mix consistency to address the policy strategy, since conflicting objectives are a major source of tensions between the instruments in a policy mix (Flanagan et al., 2011). Consistency of the policy strategy comprises three sub-levels. First, objectives ought to be consistent (Mickwitz et al., 2009a; OECD/PUMA, 2003), suggesting that they can be achieved simultaneously without any significant trade-offs. Examples are whether climate targets are consistent with renewables or energy efficiency targets, or whether interim targets are consistent with long-term targets. Second, principal plans, i.e. framework conventions, guidelines, strategic action plans and roadmaps, ought to be consistent. For example, the German Energy Concept (2010) can be seen as strategic action plan which further specifies the preceding and more overarching “Energiewende” framework in a relatively consistent manner. Third, principal plans should be consistent with policy objectives. An example for this is that the German Energy Concept (2010) confirms the German 40 % GHG emissions reduction target until 2020 as originally specified in 2002.

The *second level* concerns consistency of the instrument mix which can be assessed through interaction analysis. The instruments in an instrument mix are “consistent when they work together to support a policy goal. They are inconsistent when they work against each other and are counterproductive" (Kern and Howlett, 2009, p.396). Therefore, strong instrument mix consistency is associated with positive interactions, weak instrument mix consistency is characterized by neutral interactions, while instrument mix inconsistency is captured by negative interactions (del Río González, 2009a; del Río González, 2010; IEA, 2011b; Sorrell et al., 2003). However, this link between consistency and interaction is rarely addressed in the literature. [25]

The ultimate test of policy mix consistency lies at the *third level*, referring to the interplay of the instrument mix and the policy strategy. First and second level consistency are only necessary but not sufficient conditions for third level consistency. This overall policy mix consistency necessitates a conflict-free, ideally synergy-creating alignment of a consistent policy strategy and a consistent instrument mix, thereby ensuring that objectives can be achieved. [26] That is, the strategy needs to be implemented with instruments that are able to reach the objectives. For example, the instrument mix operationalizing the German Energiewende is currently sometimes perceived as inconsistent with its ambitious targets, which may slow down the envisaged transition of the energy system (ARD 2013, WDR 2013).

Consistency at these three levels may ultimately determine the effectiveness and efficiency of a policy mix. Yet, particularly due to the variety of often conflicting interests and the vertical and horizontal fragmentation of policy making, complete consistency of a given policy mix may be unlikely, if not impossible (Hoebink, 2004; McLean Hilker, 2004). This is particularly true the broader the boundaries of a policy mix study are set. Given these limitations, the question thus becomes how policy processes can be designed to at least limit policy mix inconsistency as far as possible, a point we turn to in the next section.

3.2 Processes

3.2.1 Policy making & implementation

The conceptualization of the policy mix so far has focused on describing its elements at a given point in time. These elements are shaped by policy processes, which, due to their importance, constitute one building block of the proposed policy mix concept (Howlett and Rayner, 2007;

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25 The few exceptions that exist (Ashoff, 2005; McLean Hilker, 2004) use the term interaction without cross-references to the interaction literature (Sorrell et al., 2003).

26 This is what Kern and Howlett (2009) refer to as congruence.

Kay, 2006). That is, rather than only looking at the content of the policy strategy and instrument mix with its interacting instruments, we now turn our attention to the policy making process, or policy process for short (Dunn, 2004; Dye, 2008). Ultimately, it is these processes, which, through the way they proceed and through their outputs, determine the consistency of the elements of the policy mix (Majone, 1976).

By policy processes we mean “the procedures and institutional arrangements that shape policy making” (Nilsson et al., 2012, figure 1). They cover all stages of the policy cycle, including problem identification, agenda setting, policy formulation, legitimization and adoption, implementation, evaluation or assessment, policy adaptation, succession and termination (Dunn, 2004; Dye, 2008; Schubert and Bandelow, 2009). Owing to the fundamental importance of policy implementation in determining the effectiveness and efficiency of a policy instrument we follow others in distinguishing policy processes into policy making and policy implementation (Richardson, 1982).

Regarding *policy making*, we stress two aspects with repercussions for the consistency of the elements of the policy mix. First, policy making can improve the consistency (or reduce inconsistencies) of the elements of the policy mix, for instance by changing policy objectives or the instrument mix. This can be accomplished by adjusting existing or adding new instruments and / or objectives (Kern and Howlett, 2009). Second, due to the dynamic, multifaceted and uncertain nature of a transition of the power sector towards renewables, policy adaptation and thus policy learning ought to feature highly within policy making processes (Allen et al., 2011; Bennett and Howlett, 1992; Kemp et al., 2007; Loorbach, 2007). This includes the strengthening of systemic capabilities of policy makers (Jacobsson and Bergek, 2011).

Regarding *policy implementation*, we highlight its role for ensuring a vertically consistent policy mix. Policy implementation captures “the arrangements by authorities and other actors for putting policy instruments into action” (Nilsson et al., 2012, figure 1), that is, for executing and enforcing them (Sabatier and Mazmanian, 1981). Even in the case that policy instruments are consistent with the policy strategy, complex and insufficient implementation structures may lead to implementation difficulties so that ultimately a policy instrument does not tap its full potential. For example, for selected renewable power generation technologies Reichardt et al. (2011, p.53) find that “administrative procedures need to be more reliable, punctual and standardized” and thus recommend that particularly in early phases of technology development policy makers and administrators should collaborate with innovators in order to ensure a smooth functioning of policy implementation. Such vertical inconsistencies may be overcome by an appropriate crafting of policies (May, 2003; Mazmanian and Sabatier, 1981), including the provision of sufficient funding and staff for implementation, thereby illustrating the close link between policy making and policy implementation.

As such, policy processes tend to be highly complex with a plethora of involved actors and their interests. For illustrative purposes we present key steps in the evolution of the German policy mix for renewable power generation technologies until 2004 (see Table 5). These policy making processes range from the promotion of initial support programs by advocacy groups and the parliament to the adoption and first amendments of the German Renewable Energy Act (EEG).

Table 5: Selected policy processes describing the evolution of the German policy mix for renewables (until 2004)

time	involved actors	policy processes
aftermath of oil crises and Chernobyl	renewables advocacy groups, parliament	promotion of initial support programs for wind and solar power, e.g. 1,000 roofs program
late 1980s to 1990	renewables advocacy associations	putting forward of Feed-in Law (StrEG)
1990	German Bundestag	adoption of StrEG in all-party consensus
	Ministry of Economic Affairs, big utilities	opposition to StrEG
mid 1990s	German Länder, municipal utilities	support of renewables through specific local programs
2000	German Bundestag	catalyzing of fast adoption of first EEG
2000 to 2004	government opposition, utilities, associations, interest groups	different degrees of disagreement for drafting first EEG amendment

Source: Own compilation based on Jacobsson and Lauber (2006), Wüstenhagen and Bilharz (2006)

Finally, we highlight the role of the *style* of policy processes. More precisely, we refer to the policy making and implementation style, i.e. the “standard operating procedures for making and implementing policies” (Richardson, 1982, p.2). The policy style captures, for example, the typical kind of goal-setting or flexibility in instrument application (Blazejczak et al., 1999; Jänicke et al., 2000). By directly and indirectly influencing the policy mix, e.g. regarding its credibility or the design and implementation of policy instruments, it may play an important role on how the overall policy mix affects innovation.

3.2.2 Coherence of processes

For characterizing policy processes we use the term coherence, thereby following those studies focusing on the process dimension (Den Hertog and Stroß, 2011; Jones, 2002; OECD, 2001; OECD, 2003; OECD/PUMA, 2003). Given the ambiguity of the literature (see section 2.2) we suggest to define policy coherence as referring to the processes of policy making and implementation ensuring that the elements of the policy mix are not in contradiction with or may even reinforce each other.

We highlight three key features of this coherence definition. *First*, it only addresses policy processes, thus explicitly excluding any characterization of the state of the policy mix. *Second*, the definition establishes a positive link between coherence and consistency, meaning that greater coherence is expected to be associated with greater consistency. However, this link is no automatism, i.e. coherence is no sufficient condition or guarantee for consistency. *Third*, the definition is comprehensive as it encompasses all policy processes across different policy fields and governance levels (see section 3.3) and targets all elements of the policy mix. By including both policy strategy and interacting instruments we underline that none of the elements of the policy mix are seen as given.

Several studies discuss how to achieve coherence of policy processes (Ashoff, 2005; OECD, 1996; 2001). According to den Hertog et al. (2004), a number of structural and procedural mechanisms for strengthening coherence have been employed in OECD countries, such as strategic planning, coordinating structures and communication networks. Coherence enhancing measures also include leadership and commitment (OECD, 1996). For example, the Energiewende in Germany was declared as “Chefsache” by chancellor Merkel, signaling leadership and commitment, although by itself this does not make up for inconsistencies in the policy mix (Welt 2012). Two major tools for improving policy coherence are policy integration

(OECD/PUMA, 2003; Underdal, 1980) and coordination (Bouckaert et al., 2010; OECD, 1996).[27] The former can improve policy coherence by enabling a more holistic thinking across different policy sectors, at the same time involving more holistic processes. In contrast, the latter can strengthen coherence by aligning tasks and efforts of public sector organizations (Bouckaert et al., 2010), e.g. in enhancing information flows through formal mechanisms (OECD, 1996). For example, the establishment of an integrated energy and climate policy department, as accomplished in the UK and Denmark, seems to be a promising approach of structural coordination for overcoming the reoccurring conflict of competences between the German federal departments for the environment (BMU) and economics (BMWi) hampering the German Energiewende (Rave et al., 2013).

While both coherence and consistency are key characteristics of the policy mix, they should be seen as relative concepts, implying that it may well be a mission impossible to actually achieve complete coherence and consistency (Carbone, 2008; McLean Hilker, 2004). The reasons for this lie in the complexity of the systems we are dealing with in which conflicting objectives between different policy fields or governance levels may be inevitable. Therefore, “the aim is to make progress towards maximum coherence within the limited resources available” (McLean Hilker, 2004), thereby striving for a maximization of policy mix consistency, or, put differently, a minimization of policy mix inconsistency.

3.3 Dimensions

The discussion so far has largely abstracted from the complex and dynamic nature of the policy mix. This broader perspective is taken up by the dimensions in which the policy mix can play out, both in terms of its elements and processes. As such this third building block can serve as starting point for setting the system boundaries. More precisely, this is accomplished by determining the key dimensions to be considered for each of the elements and processes of a policy mix, as illustrated by Table 6 for the case of renewables in Germany. Relevant dimensions may include, but do not have to be limited to, the policy field, governance level, geography, sector, technology, value chain position, innovation phase, actors and time. In the following we briefly introduce each of the nine dimensions of the policy mix.

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27 See definitions provided in footnotes 10 and 11. Also, while some studies view coherence as equivalent to integration and coordination (Duraiappah and Bhardwaj, 2007; Geerlings and Stead, 2003), we follow others in seeing them as distinct formalized tools for improving policy coherence (Carbone, 2008; Di Francesco, 2001; McLean Hilker, 2004; OECD/PUMA, 2003).

Table 6: Some choices for setting the boundaries of the policy mix for renewables in Germany

Dimension	application to policy mix for renewables in Germany
policy field	climate, energy, innovation, environment, industrial and others
geography	Germany, regions
governance level	EU, national, regional, local; departments, implementing agencies
sector	power
technology	renewable power generation technologies, e.g. wind, PV
innovation phase	invention, innovation, diffusion
actor	policy makers (e.g. EU commission, German government) target actors (e.g. private investors, grid operators, households)
value chain position	manufacturing, project development, installation, power generation operation & maintenance
time	static (e.g. 2009), dynamic (e.g. 1991 to today)

The first dimension *policy field* refers to the policy domain, such as energy policy, environmental policy, climate policy, innovation policy, technology policy, science policy, industrial policy and transition policy (van den Bergh et al., 2007). For instance, a policy strategy aiming at the promotion of renewable power generation technologies does not have to originate from the field of climate or energy policy but instead could be based on a mix thereof or on industrial policy only. Also, the instruments in an instrument mix can typically be attributed to one primary policy field, such as the EU ETS to climate policy. The same may hold for policy making and implementation processes, keeping in mind that a transition to renewables typically involves more than one key policy field.

For the second dimension *governance level* we focus on the distinction between vertical and horizontal, as done in studies on policy coherence and consistency (e.g. Carbone, 2008; Den Hertog and Stroß, 2011; den Hertog et al., 2004; Duraiappah, 2004; Pal, 2006). The vertical level differentiates between the EU and the Member States, but also between a regional and international level. It further distinguishes between government departments and implementing agencies. For example, in the first and second EU ETS trading phase policy making has occurred both at the EU and Member State level, while its implementation has predominantly taken place at the Member State level. In contrast, the horizontal level allows for differentiating between different political or administrative entities at the same vertical governance level, such as federal departments of different policy fields. An example is the German Energiewende, for which horizontal coherence becomes a particularly great challenge due to the involvement of six departments[28].

Third, closely related to this abstract space of governance level is the *geography* dimension, constituting the space in which the policy mix plays out. This implies a focus on where the impact of a policy mix takes place and underlines the increasing attention to the role of a geographical perspective in transition studies (Coenen et al., 2012; Raven et al., 2012; Späth and Rohracher, 2012). An example would be policy instruments targeted towards a certain geographical region, such as a funding initiative for the deployment of renewable power generation technologies in a specific community.

The fourth and fifth dimensions of the policy mix are the *sector* and the *technology*. They allow, for example, to delineate policy mixes within sectoral or technological innovation systems (Hekkert et al., 2007; Malerba, 2004), such as the policy mix relevant for the technological innovation system for PV. Also, a policy instrument can target and affect (a) certain sector(s) or certain technologies. An example for the former is the EU ETS, which initially covered larger installations within the energy and industry sectors only, while an example for the latter is the European Energy Programme for Recovery (EEPR), which only addresses selected low-carbon power generation technologies.

Sixth, closely related to the technology dimension is the dimension of *innovation phase*, as technologies run through different – not necessarily linear - innovation phases, which may also be reflected in the functioning of the corresponding technological innovation systems. Policy mixes should be adjusted accordingly, so as to consider changing needs, which may be best addressed by adjusting its elements, particularly its instruments (Foxon et al., 2005; Rennings et al., 2008). Another way of considering this dimension is highlighted by findings indicating that for invention and innovation firms in the power sector assign a higher relevance to long-term climate targets, while for diffusion the EU ETS plays a greater role (Rogge et al., 2011a).

Seventh, an essential dimension for studying the evolution and effects of policy mixes is the *actor*, that is, the decision-making entities and their behavior, such as authorities, companies,

28 These are the Ministries of economy, environment, education, transport & buildings, finance, food & agriculture.

non-governmental organizations and individuals. A particularly useful distinction is that between actors involved in policy making and implementation, on the one hand, and target actors, i.e. those being affected by the resulting policy mix, on the other hand (Mickwitz, 2003), although the latter may also be involved in policy making, e.g. through interest groups. The diversity of these target actors may call for the need of tailoring a policy mix to better address this heterogeneity (Schmidt et al., 2012a).

Eighth, the *value chain position* indicates the location of a firm within the market (Cox and Lamming, 1997) and captures “the physically and technologically distinct activities a firm performs” to create a product (Porter, 1985, p. 33). For example, the location of a firm within such a value chain was shown to be important for explaining innovation effects of the policy mix in the power sector, e.g. by identifying trickle down effects of the EU ETS (Rogge et al., 2011b; Schmidt et al., 2012b). Finally, a key link exists between this dimension and the one on technology, as value chains typically differ across technologies.

Finally, *time* is another crucial dimension in the policy mix concept as it allows for capturing its dynamic nature both in terms of its elements and processes. That is, first, all elements of the policy mix change over time which we illustrate using the example of the evolution of the elements of the German policy mix for renewables from 2000-2013. As can be seen in Figure 1, both the policy strategy and the instrument mix have changed over the years, with new elements being added and existing ones being amended. However, the policy strategy and policy instruments may not only change in terms of their contents, ideally resulting in continuous improvement (Kivimaa, 2007), but also in terms of their effects as they are interpreted against changing rationales (Flanagan et al., 2011). Similarly and resulting from changing instruments, interactions are not stable over time either, possibly causing the instrument mix to drift out of alignment (IEA, 2011b; Sorrell et al., 2003). Second, policy processes may also change over time (Flanagan et al., 2011), and should be characterized by adaptive policy making to allow for adjusting the policy mix as “the world changes and new information becomes available” (Walker et al., 2001, p.283). This key requirement has been recognized in the literature on policy learning, e.g. in the context of transition management (Loorbach, 2007; Rotmans et al., 2001).

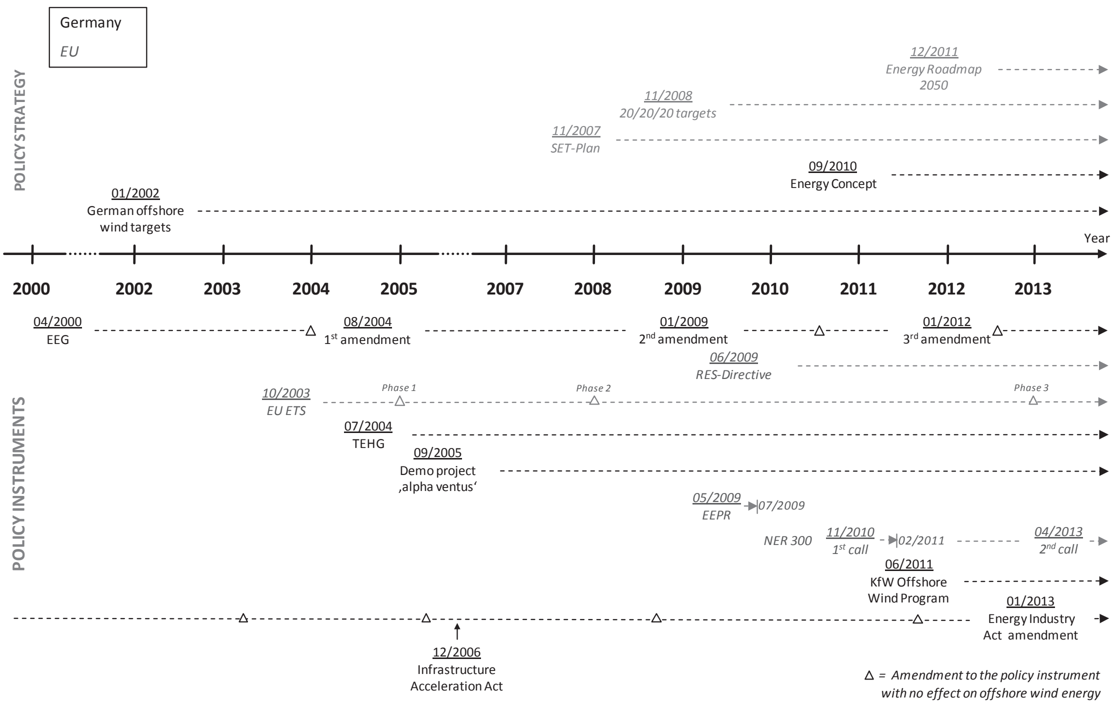
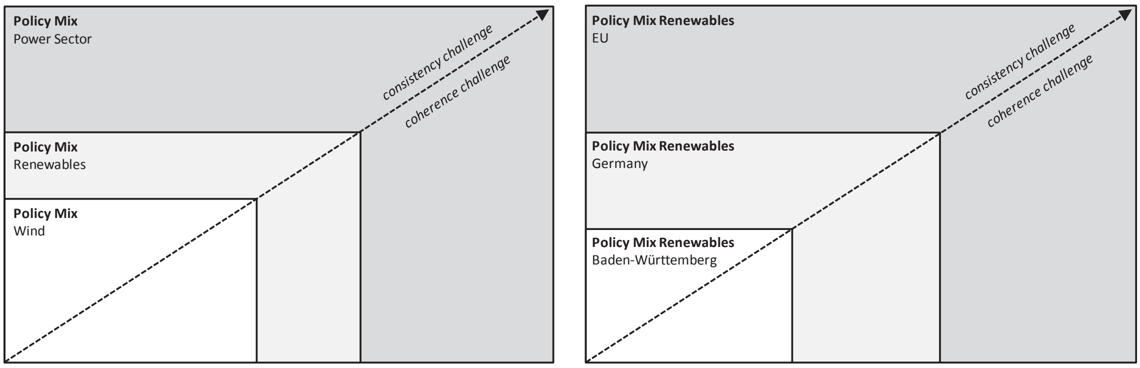


Figure 1: Development of the policy mix for renewables in Germany (example of offshore wind in Germany)

The specification of the dimensions determines not only the scope of the policy mix but also the feasibility of achieving policy mix consistency and coherence. For example, a study on the policy mix regarding renewables could focus on one specific technology (e.g. wind), widen its scope to all renewable technologies or assume a holistic energy sector perspective, as illustrated in Figure 2 (a). In addition, taken the technological focus on all renewables as given, boundaries should also be determined concerning other key dimensions, e.g. regarding the vertical governance level, for which Figure 2 (b) provides some examples ranging from the state of Baden-Württemberg in Southern Germany to the EU. The wider the boundaries are set the greater the complexity of the policy mix and thus the greater the challenges for consistency and coherence, as indicated by the arrows in Figure 2. Yet, while narrow boundaries may allow for a reduction of complexity and increase of depth both researchers and policy makers should keep in mind the effects of widening the system boundaries and thus the scope of the policy mix.

Figure 2: Link between policy mix boundaries based on dimensions and consistency/coherence



(a) Dimensions technology & sector

(b) Dimensions technology & governance level

3.4 Synopsis

After having introduced the three building blocks we now integrate them into a comprehensive policy mix concept (see Figure 3) in which elements and processes constitute the core, while the dimensions serve to specify them.

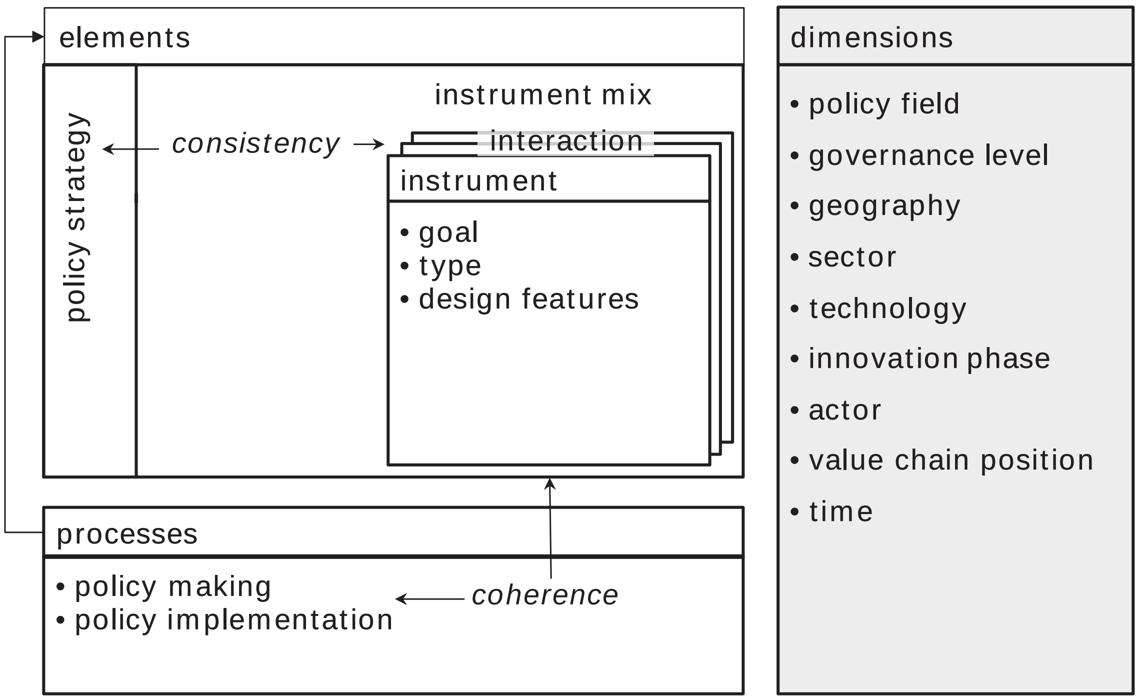


Figure 3: The policy mix concept

First, regarding the *elements (E)* of the policy mix the concept not only includes the instrument mix – comprised of interacting policy instruments characterized by their goals, type and design features – but also the policy strategy, i.e. long-term policy objectives and principal plans (section 3.1). The policy mix concept captures the state of affairs of these elements by the term consistency, for which three levels are distinguished (section 3.1.4): (1) consistency of the policy strategy, (2) consistency of the instrument mix, which is determined by the interaction of the instruments, and (3) consistency between policy strategy and instrument mix (as indicated by the double-sided arrow in Figure 3).

Second, by incorporating policy *processes (P)* the concept includes the procedures and institutional provisions of policy making and implementation (section 3.2). These processes determine the policy mix elements (as indicated by the left-hand arrow in Figure 3) and are characterized by the term coherence (section 3.2.2). The concept foresees a positive link between coherence and consistency as it may influence the state of affairs of the elements of the policy mix (as indicated by the lower arrows in Figure 3; sections 3.2.2).

Finally, the proposed policy mix concept reflects the complex and dynamic nature of policy mixes by its *dimensions (D)*. These can serve to specify elements and processes and their characteristics. For example, a study could analyze the temporal consistency of the policy mix *(D: time)*, its horizontal coherence *(D: governance level)*, the policy mix promoting a specific technology *(D: technology)*, or the most influential actors in the policy making process for a new policy instrument *(D: actor)*. As such, the dimensions can serve for setting the boundaries of a policy mix.

4 Discussion

In this section we explore the significance of the policy mix concept by discussing how its building blocks of elements *(E)*, processes *(P)* and dimensions *(D)* play out in real-world policy mixes, taking the case of renewable power generation technologies in Germany as an example. Regarding this case, German policy makers and other stakeholders currently appear to be preoccupied with reforming the EEG with its feed-in tariffs - the core instrument of the German policy mix for renewables *(E: instrument)*. Somewhat ironically, a key reason for these reform efforts lies in the effectiveness of the EEG in (over)achieving its goals for the diffusion of renewables in Germany *(E: instrument – goal)* (Ragwitz et al., 2012). This success suggests inconsistencies within the EEG, particularly regarding PV *(D: technology)*, but also within the broader policy mix, including interactions with the EU ETS *(E: instrument mix, consistency)* resulting in high costs.[29] So far, this has been addressed by changing the EEG, e.g. adjusting goals upwards and tariffs downwards *(E: instrument – goal, design features, P: policy making)*[30].

Yet, due to the magnitude and sustained increase of the EEG costs, discussions are now underway about the (partial) substitution of the EEG with other instruments *(E: instrument – type, instrument mix, P: policy making, D: time)*. For example, future demand-pull instruments may include spatial specifications for priority areas for capacity additions to recognize the trade-off between physical potential, such as wind or sun, and the distance to demand centers and thus grid requirements *(E: instruments – type, design features, D: geography)*. That is, a future instrument mix *(E)* aiming at cost efficiency will not only have to consider EEG costs but also associated costs to build up additional grid infrastructures (Agora Energiewende, 2013).

Another example concerns the discussion of a retrospective adjustment of previously guaranteed feed-in tariffs received by operating plants initiated by federal minister of the environment Peter Altmaier in the beginning of 2013 *(P: policy making, E: instruments – design features, D: actor)* (Spiegel Online, 2013a). His suggestion, which was later dropped *(D: time)*, shook up the very foundations of the belief system of investors by questioning the so-called “Bestandsschutz”, or right of continuance, thus ultimately casting doubt on the predictability of the EEG but to some extent also on the credibility of the policy strategy *(E: instrument - design feature,*

29 The so-called EEG-Umlage increased from initially 0.19 ct/kWh in 2000 to 3.59 ct/kWh in 2012, representing a share of electricity costs of now nearly 14 % for households (BMU, 2013).

30 For the case of PV this policy process was described as compulsive policy making (Hoppmann et al., 2012).

policy strategy). While so far the elements of the policy mix have remained unaffected, merely this discussion may have had a detrimental effect on investors and innovators (Spiegel Online, 2013b), illustrating the importance of including policy processes and their coherence within a comprehensive policy mix concept *(P: processes, coherence)*.

In this regard, the German government pursues several routes of improving policy coherence *(P – processes, coherence)*. Renewables have been under the auspices of the German environmental department since October 2002[31], a structural change which improved policy coherence and eased the integrated consideration of demand-pull and technology-push and some of the systemic concerns of a transition to renewables *(P: policy making, coherence, E: instrument – type, instrument mix, D: policy field, time)*. [32] More recently, the problematic developments regarding ever increasing EEG costs and other concerns have been addressed by enhancing procedural coordination and thus policy coherence *(P: policy making, coherence, D: time):* First, a renewables platform was established on April 25, 2012 uniting federal and state-level policy makers from various departments *(D: governance level)* as well as non-governmental stakeholders *(D: actor, value chain, governance level)* [33] to jointly develop solutions to identified transition challenges (BMU, 2012). Second, a public debate about the EEG ("EEG-Dialog") was organized in a series of six meetings taking place from November 2012 to March 2013 to discuss problems, conflicts and alternative solutions regarding the reform of the EEG *(P: policy making, D: actor, technology, sector)*.[34]

Yet, considering the highly ambitious policy strategy associated with the Energiewende these and other current political discussions appear to be too fragmented between climate, renewable and energy efficiency policy *(D: policy field)* and not systemic enough. This is exemplified by the attention given to reforming the EEG *(E: instrument – design feature, type)* and the neglect

31 See BMU 2013 for a historical account of the development of the BMU and Rave et al. (2013) for an overview of all departments involved in different aspects of climate, energy and innovation policy.

32 This structural coordination may have contributed to the successful development of the German technological innovation systems for renewables (Walz and Ragwitz, 2011).

33 E.g. industry associations, grid companies, and environmental NGOs, see (BMU, 2012) for a complete list of participants.

34 The debate among different stakeholders was organized around different technologies (PV, biogas, wind, storage) as well as scenarios and costs *(D: technology)*.

of also reforming the EU ETS with its low carbon prices (Germanwatch, 2013)[35], despite their interaction and potentially complementing role for incentivizing investments in renewables *(E: instrument mix, second level consistency)*. Also, while demand-pull for renewables and systemic concerns regarding market design for the power sector are increasingly being discussed in an integrated manner, this seems to be neglected for technology push concerns *(P: policy making, E: instrument mix – type, D: sector, technology, time)*.[36] For example, none of the three working groups on the platform renewables prominently addresses the importance of combining demand-pull with technology push instruments, despite recommendations in this regard (Foray et al., 2012; Veugelers, 2012; Walz and Ragwitz, 2011).[37]

Based on this, we derive three main policy implications. *First*, the paper underlines the importance to think in terms of policy mixes rather than single instruments, and provides an analytical framework assisting in assuming such a broader perspective. [38] More precisely, it highlights the need for policy makers to not only think in terms of instrument mixes and instrument interactions, but to consider the policy strategy with its long-term orientation as an equally important element of a policy mix.

Second, since policy processes not only determine the elements of the policy mix but can also have a direct effect on the behavior of target actors, policy makers do not only need to work on improving the consistency of the elements of the policy mix but also the coherence of policy

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35 EUA prices have dropped from ca. 22 € in the second half of 2008, to ca. 12 € in December 2010 and 6 € in December 2012 *(D: time)* and - with the failure to adopt “backloading” by the EU parliament on April 16, 2013 *(P: policy making)* - are at a current low of ca. 3-4 € / EUA (EEX 2013, xxx 2013).

36 One indicator of this neglect is the low share of 4.8% of RES expenditures going to technology push instruments, while the rest is associated with the demand pull costs of deployment instruments (Rave et al., 2013). Yet, the optimal balance between expenditures for demand-pull and technology push is an open question, whose answer may depend on several dimensions, e.g. which technology is being targeted and its innovation phase *(E: instrument mix – type, D: technology, innovation phase)*.

37 The three working groups deal with deployment instruments (mainly EEG), coordination of deployment plans and impact for grids, and interplay of renewable and fossil power generation technologies (BMU, 2012).

38 This could be further assisted by adapting existing policy databases and their search categories, such as IEA’s policies and measures (http://www.iea.org/policiesandmeasures) or the EU’s MURE database (http://www.muredatabase.org/) to better reflect the different elements (and processes) of the policy mix and their dimensions, and thus ease the access of information about a policy mix.

processes. However, coherence and consistency are not ends in themselves but their relevance arises from the effects they have on the effectiveness and efficiency of a policy mix.

Third, the paper points to the necessity to assume a system's perspective in policy making. For example, an instrument mix should not only address demand pull or technology push but cover all concerns, including systemic ones. Also, even when reforming one single instrument policy makers working on the objective 'Energiewende' need to keep in mind how the proposed changes affect the consistency of the overarching policy mix. This requires systemic capabilities, e.g. in terms of assessing the needed changes to an existing policy mix to promote the functioning of an innovation system. Such capabilities could be supported through coherent policy processes and further developed by policy learning.

5 Conclusion

This paper contributes to the literature at the nexus of policy, innovation and sustainability in two major ways. *First*, it suggests a comprehensive concept of the policy mix recognizing the complexity and dynamics of real policy mixes and provides a uniform terminology applicable across academic disciplines. More precisely, the concept stresses that a policy mix goes beyond the combination of instruments – the instrument mix – but also includes a policy strategy, and policy processes. In addition, the paper supports the precise use of key terms by providing uniform definitions, thereby enabling interdisciplinary research and enhancing the comparability of policy mix studies. A prime example in this regard is the suggested distinction between consistency (for elements) and coherence (for processes). *Second*, the paper provides an interdisciplinary analytical framework which may aid empirical research in at least two ways. First, the three building blocks of elements, processes and dimensions with their subcategories can assist in setting the boundaries of a policy mix study and thus in concretizing its scope and depth, keeping in mind the tradeoffs between the two. Second, by explicitly differentiating between policy mix characteristics and assessment criteria the paper points to the importance of studying the link between coherence and consistency, and efficiency and effectiveness.

Yet, the comprehensive policy mix concept proposed in this paper is not free from limitations. *First*, since it has been developed for the case of renewables it may not be generalizable to other societal challenges; yet, the concept may still serve as useful starting point. *Second*, the comprehensiveness of the policy mix concept proposed here comes at the cost of providing only a rather aggregated overview of the three building blocks, their characteristics and their interplay.

Thus, we envisage three areas for future research. *First*, the policy mix concept proposed here should be further developed by a more detailed examination of each of the three building blocks. In this regard, it may be especially promising to explore in more depth the nature of policy processes and their coherence, and their influence on the elements of a policy mix and their consistency. Also, future studies could further develop policy mix characteristics other than consistency and coherence, such as comprehensiveness, credibility and stability. A *second* promising field of future work represents the integration of the policy mix concept with other research approaches, such as studying the co-evolution of policy mixes and innovation systems, or the role of policy mixes within socio-technical transitions as analyzed by the multi-level perspective. *Finally*, empirical studies would benefit from applying the analytical framework proposed here to better understand the role of the policy mix – with its elements, processes and characteristics – for key assessment criteria, such as its dynamic efficiency and thus its innovation effect, e.g. through case studies, company surveys, patent analyses or modeling. In particular, studies should shed light on the link between coherence and consistency, and how these affect the effectiveness and (dynamic) efficiency of policy mixes. Within this research, two key methodological challenges will be the operationalization of policy mix elements, processes and their characteristics, and disentangling the effects of the different constituents of a policy mix, such as different instruments and the policy strategy.

We conclude that the comprehensive policy mix concept presented in this paper with its suggestions for a uniform language across disciplinary boundaries lays the foundation for arriving at a more realistic understanding and analysis of policy mixes and their effects, thereby enabling more concrete policy recommendations particularly in the light of sustainability transitions.

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The eco-restructuring of the Ruhr area as an example of a managed transition

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Content

Content 2

1. Introduction 3

2. Research Methodology and Analytical Framework 4

3. The Ruhr Area and its socio-economic transition 5

4. Blue Skies above the Ruhr 6

5. Reconstruction of the Emscher river system 8

6. The emerging energy transition 11

7. Differences and interrelationships between the Emscher and Bottrop show case projects 13

8. Regional and supra-regional elements 16

9. The lessons for transition management 20

BIBLIOGRAPHY 23

1. Introduction

In this paper we will examine the process of eco-restructuring of the Ruhr area in Germany in the 1970-2012 period in the form of a cleaning up of a polluted area, the creation of eco-industry and a shift towards renewable energy in a coal and steel industry dominated area. We conceptualise this process of restructuring as a managed sustainability transition because of the use of various programs and acts to achieve an ecological modernization and the creation of a new identity for the region. It wasn't managed on the basis of a masterplan, but "managed" through sustained policy and industry actions.

In the paper, we describe the management and real-world experimentation element of the eco-restructuring, with special attention to the institutional actors behind the change, the motivating visions and financing element.

The story of eco-restructuring in the heavy industry dominated, polluted area of NRW contributes a case of a purposive transition to the literature of sustainability transitions. The story goes beyond an examination of green innovation in niches, and is able to draw conclusions about transition management.

The structure of the paper is as follows. Section 2 states the research questions that we will investigate and explains the methodological choices of the research on which the paper is based. Section 3 describes the historical setting of the Ruhr area as the industrial heart of Germany and Europe. Section 4 discusses the vision of "blue sky" above the Ruhr and the increase in government activity for the protection of the environment based on the idea of ecological modernization. Section 5 zooms in on one important projects of the Ruhr transition to a greener economy: the Emscher Landscape Park initiative (a 4.5 bn euro "generations project" for converting the dirtiest part of the Ruhr into a space for recreation, culture, working and living) and the low-carbon Innovation City Ruhr initiative as two high-profile initiatives based on a partnership between the North Rhine Westphalia government, city governments, business and civil society. Section 6 discusses the energy transition of NRW as a new political project for the Ruhr area, where we describe the energy transition (energiewende) NRW towards sustainable energy and the innovation city Bottrop as an important energy transition initiative in the Ruhr area. Section 7 examines the institutional element and differences and interrelationships between the three processes: the introduction of environmental laws giving rise to an eco-industry sector, the clean-up and urban revitalization of the Ruhr area and the emerging energy transition. Section 8 focuses on the local and supra-local element in considering the role of national and international policies vis-à-vis regional policies. Section 9 draws conclusions about what the case of eco-restructuring in North Rhine Westphalia learns about transition management.

2. Research Methodology and Analytical Framework

Methodologically the paper makes use of secondary sources for the description for the historical context, relevant initiatives and policy acts. Because the history of the Ruhr transition has not been documented, we had to rely on grey literature and internet sources as the main sources of factual information. The information was compiled in cooperation with central regional stakeholders such as the Emschergenossenschaft/Lippeverband (EG/LV), Regionalverband Ruhr (RVR), Wirtschaftsförderung Metropole Ruhr (wmr), the Landesamt für Natur, Umwelt und Verbraucherschutz NRW (LANUV) as well as representatives of the cities of Bochum and Essen. The information was presented and discussed in a sequence of conferences and workshops with governmental and non-governmental stakeholders of the Ruhr area. Details of the stakeholder meetings (in terms of place and participants) are described in the Appendix.

The paper is a first draft, based on our interpretation. At a specially organized workshop with key insiders we will jointly examine the importance of the different elements of transition management (role of visions and strategic foresight, special arenas for interaction and deliberation, special transition experiments for learning and innovation and strategic actions for institutional change). At the workshop the findings of the present paper will be presented and further discussed. The workshop will reveal to what extent the actors involved hold different views on the causal mechanisms and facilitating factors. The "reality check" by decision makers of our own interpretations of determining factors and the confrontation of various perspectives, followed by post-workshop analysis, will help to create socially robust knowledge.

Analytically the paper is based on three frameworks: i) the model of *transition management* which attributes great significance to visions and foresight as strategising tools, special arenas for discussing and determining transition goals and transition initiatives that act as stepping stones for transitional change, strategic action linking niche developments with regime and landscape developments (Loorbach, 2007, Kemp et al., 2007; Rotmans and Loorbach, 2010) ii) the *institutional economic geography perspective* to transition analysis as a framework for studying how processes of geographically uneven transition pathways are shaped and mediated by institutional actors and structures at different scales (Coenen et al, 2012), and iii) the *politics of transition perspective* (Kern and Smith, 2008; Meadowcroft, 2009; Voss et al., 2009; Kemp, 2011) by examining questions such as: who governs, whose systems counts and whose sustainability gets prioritised in transition management policies? (Smith and Stirling, 2010).

3. The Ruhr area and its socio-economic transition

The Ruhr area is Germany's largest urban conglomerate compromising 11 cities and 4 districts in the northwestern part of the federal state of North Rhine-Westphalia. With a population of 5.2 million (2012)[1], a local GDP of €140 billion (2009) (LIT 2013) and a labour force of 1.7 million (2012) (BA 2012) it is one of Europe's most important industrial clusters.

The Ruhr area is named after the river Ruhr that crosses the south of the region from east to west. In Germany the name itself has become synonymous for the production of coal and steel and later for the crisis of heavy industries and structural change.

What is now an urban agglomeration, was 200 years ago a rural area of small settlements. The development of the region towards an urbanized industrial region started with the beginning of the German industrialization and the rising demand for energy in the 19th century. The huge coal deposits of the region led to an establishment of numerous mines and steel works. During the 19th century the region became the backbone of Germany's coal and steel industry.

The Ruhr industry not only helped Germany to become one of the most industrialized countries but also was the armour factory in both world wars. After World War II it was the basis for the German rapid economic recovery (*wirtschaftswunder)*. Having had a population of about 200,000 in the early 19th century, it rose to 4 million before World War I and to 6 million in the 1950s. The massive increase in labour force promoted a rapid increase of the output of coal and steel. During the 1920s-1940s the output of steel of the Ruhr area exceeded total steel production in Great Britain. In the 1930s every 6th ton of steel consumed worldwide was produced in the Ruhr area (Schlieper et al. 1986, Kelly, Matos 2010). The production of production peaked in the 1950s when more than one million people were employed in the steel and coal industry[5], which was roughly 70% of the whole labour force of the Ruhr area.

The economic decline of the Ruhr area began in the 1960s when the world market prices for coal and steel fell below the production costs of the Ruhr industry. New mines in the U.S. and Eastern Europe supplied the markets with cheap coal mined near surface, while the average mining depth in the Ruhr was 650 meters in 1960. The demand also began to shift from coal to oil. The results were large-scale closures of factories and mines. Between the 1960 and 1990 more than half a million jobs in the Ruhr were lost in the rapidly declining coal and steel industry [5]. During the 1960s the massive German economic growth compensated for the job loss. Later, the structural change lead to an unemployment rate of 15% in the region in the 1980s and a massive emigration of citizens (Reicher 2011).

In order to mitigate this development, both the state government and the federal government started to support the mining industry with subsidies. The German coal industry was funded with €295 billion (in 2008 prices) in total between 1950 and 2008 (Meyer, Eidems 2009). The largest share went to the

Ruhr area. Simultaneously, the state started to invest in higher education, establishing five universities and 16 universities of applied science. As of 2012 223.000 students were enrolled in these universities.

The structural change of the Ruhr area's economy coincided with the rise of environmental awareness.

4. Blue Sky above the Ruhr

In 1961 during the federal electoral campaign the social-democrat's candidate for chancellor Willy Brand said something remarkable: "The sky above the Ruhr has to turn blue again" (Vierhaus 1994: 86, own translation). This idea, which now appears a perfectly reasonable policy goal, was a radical idea at the time, because pollution was viewed an inescapable element of industrialisation. The following historical summary of the rise of environmental awareness in Germany marked by Brandt's historical speech is largely based on Brüggemeier et. al. (2012).

When Brandt called for a Blue Sky above the Ruhr, 300.000 tons of dust particles fell from that sky, in some quarter of the Ruhr area it was more than 5 kg per 100 square meter. In 1961 the population of the Ruhr area had to endure 1,5 mio tons of dust, fly ash and other particles as well as four million tons of sulphur dioxide in combination with a number of other harmful substance emitted by the booming coal, steel and chemical industry. These figures indicate that environmental conditions were very bad. Clinical research revealed that children, who grew up in the Ruhr area were often smaller, weighted less and suffered more often from rachitis than the children in other regions in Germany. Their fathers often working in these emitting industries died more often from cancer. The view that Ruhr area was a dangerous environment; came out of scientific research, to which Brandt make references in his speech (Weichelt 1997). Alarming facts also came from the Siedlungsverband Ruhrkohlebezirk (SVR), an association of Ruhr municipalities, saying that the environmental conditions constituted an assault (*Generalangriff)* against the region (Brüggemeier/Rommelspacher 1992: 63).

The speech of Brandt marked the beginning of a change of consciousness towards a new broader understanding of progress. Until then the traditional symbol of progress were smoking chimneys, but Brandt's slogan called for a completely different approach: of reducing pollution instead of diluting it.

Before Brandt's speech, there had been voices of concern about the high levels of pollution and health hazards. Protests started in civil society, and shifted to politics, which showed more and more interest in the issue. In December 1955 the NRW parliament had a first debate about air pollution and in the succeeding year it was put on the agenda of the German federal parliament (Bundestag). The national media started to report about air pollution. The christian-democrat's government in NRW reacted and in 1960 the NRW prime minister Franz Meyers talked about his concerns at the federal congress of the German christian-democratic party but this met little response (Weichelt 1993; Hünemörder 2004: 89ff.) .

In contrast to Franz Meyer in 1960, the reaction to Willy Brandt's speech in 1961 was overwhelming, especially in the Ruhr area where people were not willing to tolerate the increasing pollution of their environment much longer and called upon regional and national politicians to take action. In 1962 the NRW parliament enacted the first regional immission act. In 1964 this was complemented by a directive with thresholds for critical substances (Brüggemeier/Rommelspacher 1992: 62f.). The breakthrough was complete when Willy Brandt's administration took office in the German federal government in 1969. His administration initiated an immediate action programme for the protection of the environment (Sofortprogramm für den Umweltschutz) and passed a whole series of pollution control measures. The government also created a number of institutions including a inter-departmental coordination group, a stakeholder forum as well a the Federal Agency for Environmental Protection (UBA).

The 1960s witnessed a strong rise in environmental awareness among the German population. Within a few years it moved from a peripheral theme into the centre of the political discourse. Hundreds of thousands of Germans organized themselves in a number of environmental citizens organizations (Wey 1982; Hünemörder 2004). Also the trade organizations of the German industry as well as the trade unions started to deal with the environment as a political agenda issue.

While pollution control was the predominant mode of environmental policies during the 1970ies and 1980ies, attention shifted to pollution prevention through the use of cleaner production processes. In 1984, Willy Brandt said that it was not only important to react to pollution, but that precautionary approaches would be necessary, including technical innovations and production processes. He mentioned that improved energy and resource efficiency and a more careful use of air, water and soils would not only decrease environmental pressure but also save costs. Such a transition would lead to a modernisation of society, improve competitiveness of the German industry and create jobs. All of this became known under the name of ecological modernisation, a concept first coined by Martin Janicke and popularised by Joseph Huber (Mol and Janicke, 2009)[1].

The general idea of an ecological modernisation was adopted by the prime-minister of North-Rhine Westphalia, Johannes Rau, and was the background against which the Wuppertal Institute for Climate, Environment and Energy and the Energy Agency NRW was founded in the early 1990ies. Even though the integration in the governance was uneven across the different economic sectors the ecological modernization became more and more a part of NRWs economic development policies (Schepelmann 2004, 2010).

[1] Over time, the term ecological modernization became the topic of discussion of social theorists (Spaargaren and Mol, 1992; Hajer, 1995; Mol and Sonnefeld, 2000) , but originally "ecological modernization was essentially a political program. It was neither a theory, nor a concept which included the social dimension of this type of modernization" but simply "a practical and normative idea for pressing for far-reaching environmental reform" (Mol and Janicke, 2009, p.2).

Ecological modernization as a political programme supported the transformation of “the largest contributors to problems in the Ruhr area into problem solvers“ (Kilper 1996: 15, own translation). An important facilitating factor was that the energy, chemical, steel and coal industries had the necessary structures and knowledge to develop solutions for the protecting the environment. Already in 1992 the NRW eco-industry produced goods and services with a value of about 10 billion EUR, which was about one third of the German production in that sector (Nordhause-Janz 1995: 67).

According to the economic development agency of the Ruhr area (Wirtschaftsförderung Metropole Ruhr, WMR) the value chain „Resource Efficiency”[2] has a turnover in the Ruhr area of € 63,3 billion. About 96,000 people were employed in about 5,500 companies, representing 6,7% of all jobs in the Ruhr area. Overall, every 10th German job in this lead market is based here.

At a time when production increases drove pollution to intolerable levels, the Ruhr area became the cradle of modern environmental policy in Germany. Brandt’s vision and promise of “Blue skies above the Ruhr” marked the beginning of a change of consciousness and policy in Germany. Environmental end-of-pipe thinking remained dominant in the Ruhr-area for more than 30 years. Strict environmental legislation was passed and large investments in environmental clean-up technologies were made. Thus, NRW invested in the health of its population and their environment, and became a first mover on the way towards an environmental goods and service industry.[3] Today, eco-industries have become a large and highly competitive pillar of the NRW economy.

5. Reconstruction of the Emscher river system

The ecological modernisation process in the Ruhr area went beyond greener production but also involved clean-up activities which were pursued as part of urban revitalisation. It goes beyond our ability give a complete description of this complex multi-level transformational process. Instead of providing an overview of relevant projects, we opt to describe a high-profile project which already has achieved tangible results: the reconstruction of the Emscher river system as an exemplary regional development plan and flagship of the ecological, economic and urban revitalization of the Ruhr area[10].

In the 1980ies the Emscher landscape had been characterised by vacant factories, closed mines and abandoned docks with mining subsidence, large heaps of mining residues and dams. On purpose this devastated landscape was chosen to stimulate and symbolize change by integrating the industrial heritage in the renewal of the Ruhr area. It aimed at an ecological, cultural and economical

[2] WMR comprises the following economic activities under the lead market „Resource Efficiency“: energy generation and energy-related services, water and waste management, eco-industries, raw materials extraction and processing, as well as environment-related activities such as engineering, laboratory, monitoring and consultancy services

[3] It is a story of necessity as the mother of invention, or as the poet Friedrich Hölderlin wrote in the Patmos poem "But where danger is, deliverance also grows".

revitalization of the Ruhr area and an increased attractiveness of its cultural and recreational facilities. To plan and implement specific projects, the Emscher Park Planning Company Ltd was established in 1988.

The structural policies symbolised by the IBA (the International Building Exhibition) did not only focus on the economic development, but also on environmental protection, nature conservation and more cooperation in the planning and administration of the region. It also wanted to preserve the industrial heritage of the area by opting for a conversion of buildings and developing industrial factories into tourist attractions.

The conversion of the Ruhr area was to be based on a series of projects that were coherent with each other. The projects were thematically organized in seven themes (Brüggemeier, Rommelspacher 1992):

- Reconstruction of the landscape: the Emscher Landscape Park
- Ecological improvement of the Emscher
- Reconstruction of the Rhine-Herne Canal as an experimental space
- Preservation and new use of industrial heritage
- Working in the park
- New forms of housing and apartments
- New opportunities for social, cultural and sporting activities.

The IBA and its succeeding plans were funded by several public and numerous private sources. In 1988 the state of NRW created the Emscher Park Planning Company Ltd with an initial funding of €18 million. In 1993, one year after the start of the IBA park, €1.3 billion were spent on projects, including €900 million from public sources from the state, the federal government and the European Union (US EPA 2006). As of 2012 the private and public funds for the IBA and its successor plans exceed by far the initial investments.

The basic idea of the Emscher Landscape Park was to convert the abandoned and industrial landscape into a new, future-oriented and clean environment with a high quality of life.

The backbone of the Emscher Landscape Park development are seven regional green corridors that cut through the Ruhr area from south to north. Originally, these green areas were defined in the 1920s by an association of Ruhr municipalities, the so-called *Siedlungsverband Ruhrkohlenbezirk (SVR).* The green areas were supposed to steer the uncontrolled growth of the merging cities of the region in order to protect sites for recreation and leisure.

Within the Emscher Landscape Park these green corridors cover an area of 450 km^2 by integrating the brownfields of the steel and coal industry in a new system of parks. In „a landscape of structural change“ 20 cities and two counties have initiated 120 projects to contribute to the Emscher Landscape Park. The projects address ten guiding principles:

- Ecology
- Water and Rainwater
- Working and Living in the Park
- Art in the Park
- Park Infrastructure
- Leisure and Tourism
- Urban Development
- Agriculture and Forestry
- Industrial Heritage
- Landmarks

A flagship project of the IBA Emscher Park is the revitalisation of the Emscher river system, a river which had been canalised and had become an open sewer full of effluent waste. Due to ground subsidence it was not possible to build and use underground sewage systems in the mining area. Therefore the Ruhr area's settlements and industries discharged all wastewater directly into the river Emscher, which was turned since the 19th century into an open sewage water. The Emscher river was considered Germany's most polluted river. The abandonment of mines in the Emscher region allowed in the 1980s to discharge all waste water underground and restore the Emscher and its tributaries. With investments of €4.5 billion over several decades, the Emscher conversion is one of the biggest infrastructure projects in Europe[4]. In the Ruhr area, the Emscher conversion encouraged several other municipalities to take similar steps of cleaning water ways and build homes and apartment buildings at the river side, thus turning low-value land into high value land. Historical industrial monuments were given new destinations, mining rail tracks were converted into bicycle routes and parks were being created too.

By giving new use to abandoned buildings and the creation of parks, the area became a more attractive place to live, work and visit. Techno-cultural highlights such as the Gasometer Oberhausen, the landscape park Duisburg-Nord, the domestic port Duisburg or the UNESCO world heritage site of Zollverein Coal Mine Industrial Complex became tourist attractions. The number of overnight stays in the Ruhr 2011 of foreign and domestic visitors nearly doubled compared to 1990. It rose from 3,588,394 overnight stays in 1990 to 7,026,396 in 2012 (+95%) (RVR 2013).

In 2010 the Ruhr area communities managed to obtain the status of official European Capital of Culture. The recycling of abandoned land with reliable and sustainable infrastructure attracted enterprises and created new jobs as well as new perspectives.

[4] For more information visit http://www.eglv.de/wasserportal/emscher-umbau.html.

The Emscher Landscape Park turned out to be not only a show case but also a vehicle for change. Based on the Emscher Landscape Park concept a number of successor plans followed such as the *Konzept Ruhr* (Schwarze-Rodrian, Seltmann 2012) and *Masterplan Emscher Landschaftspark 2010*. As of December 2012 212 projects had been realized and 240 more are yet to come (RVR 2013).

6. The emerging energy transition

We now turn to the third element of the *Ökologischer Strukturwandel* in the Ruhr area: the transformation of the Ruhr area from a centre of fossil industries to a centre of sustainable energy industries. Since 2000 the installed power of renewable energies rose nearly exponential from 30 MW to 588 MW in November 2012 (Amprion 2012). This trend continues and is driven by public plans to invest in renewable energies.

The energy transition in the Ruhrgebiet and NRW is conditioned by the *energiewende* (energy transition) the national political project of the German Federal parliament with the following: to phase-out nuclear power by 2022, to achieve a general increase in energy efficiency and achieve a higher share for renewables in the energy mix (Bundesregierung 2010).

The phase-out of nuclear mandated by parliament, necessitates extra power capacity and creates room for the use of renewables. It implies nothing less than an overhaul of the existing system. During the phase-out of nuclear power plants the German security of supply has to be secured on the one hand, and on the other hand the network of transmission lines must be optimized for decentralised sources of renewable energy. As one of the most important energy clusters in Europe, the Ruhr area is considered of strategic importance, and makes it eligible for support from national policies besides regional policies. It also benefits from international policies, in particularly from EU Structural funds, which have been utilised to great effect to fund local projects.

Even when the national energy transition necessitates changes in the Ruhrgebiet and offers economic opportunities, *making* a transition to green energy in the Ruhrgebiet is a difficult issue for the regional government because of the coal industry and resistance of power companies who want to make their own invest decisions. Rather than fighting the resistance, the government of NRW orients itself to the opportunities that green power affords through its innovation and economic development policies. In Germany, regions have their own innovation policies, which are oriented towards economic activities in those regions. In NRW innovation and regional development policies are organised along the value chains of 16 areas of competence (VDI 2009). Environmental technologies, Energy RTD as well as logistics are clusters in which business and knowledge actors from the Ruhr area play an important role. The fact that in the Ruhr area companies have traditionally considerable competencies in energy is beneficial for obtaining innovation support; it is why companies and research institutes have benefitted so much from regional and national innovation policies and from supporting agencies including regional development agencies but also thematic agencies such as the Energy Agency NRW.

The research competences in energy are mobilised through the normal science systems and various innovation policies but also by the *energiewende* in NRW project, an ambitious programme of the government of NRW to shift to low-carbon energy and reduce energy use. According to the Ministry for Climate Protection, Environment, Agriculture, Nature Conservation and Consumer Protection of North Rhine-Westphalia it consists of the following 8 measures MKULNV (2011):

1. The NRW Climate Protection Law: In 2011 the state government established Germany's first Climate Protection Law, which aims at reducing greenhouse gas emissions in NRW by 2020 by at least 25% and by at least 80% by 2050 compared to 1990 levels.
2. The Climate Protection Start Program: This investment program is supposed to allocate several hundreds of million euros of loans and grants to support low carbon investments in the NRW industry.
3. The New Wind Energy Adaption: To stimulate growth especially in machine and plant engineering the state government set the goal to quadruple the share of wind energy in the electricity supply by 2020.
4. Cogeneration: According to studies commissioned by the NRW government[24], 35% of CO_2 emissions and 35% of raw materials can be saved in NRW's power generation through more effective use of cogeneration in power plants. Therefore, the state government has initiated an investment program "Cogeneration", allocating € 250 million over several years.
5. Research: The state encourages research for tapping new sources and locations for renewable energies.
6. Networks and Storage: To strengthen the supply of renewable energies, the state plans to enhance the network of power transition lines by 400 km and to quadruple the capacity of pump storage power plants.
7. Rhein-Ruhr District Heating: Especially in the densely populated Rhein-Ruhr region heat sources in existing and planned power stations as well as renewable sources of heat and waste heat systems will be promoted.
8. Resource Efficiency: With the Efficiency and Energy Agencies, the competition "Ressource.NRW" and an efficiency loan from the public NRW Bank for businesses the NRW government intends to promote energy and resource efficiency.

A flagship initiative for the energiewende in NRW is Innovation City Bottrop. In 2010 Bottrop won the Innovation City Ruhr competition for energy efficiency, an initiative of The Initiativkreis Ruhr, a group of private companies. The goal of the Innovation City Ruhr project is to reshape an existing city - with all its industrial facilities, green spaces, and neighbourhoods - old and new - along more sustainable lines (Reicher 2011). 16 cities participated in the competition in which the city of Bottrop succeeded with a large participatory blueprint for a low-carbon transition process. Interestingly, the 15 municipalities which participated in Innovation City competition have now created a network in order to learn from the experiments and solutions developed in Bottrop.

The stated goal of Innovation City Bottrop is to halve CO_2 emissions by 2020 in an area of 25 square kilometres and 14,500 buildings (Lechtenbömer, Fischedick 2012, Reicher 2011). The targeted area includes several neighbourhoods in the urban south of Bottrop and represents in many ways the rich cultural and social diversity of the Ruhr area. Housing, employment, trade and commerce are intertwined in a small area. By 2020 the city plans an exemplary application of a number of innovations in energy efficiency, decentralised power generation and electric transport.

Unlike other eco-city development schemes such as Masdar City in the United Arab Emirates or Dongtan in China, Bottrop developed solutions in a bottom-up way, through collaboration between scientific institutions, business, politics and civil society.

Innovation City Ruhr is a "Realexperiment" (Groß et al 2005) for the Ruhr area, NRW and for the German energy transition (*energiewende*) (Reicher 2011).

The city plans to undertake approximately 100 projects in the following areas:

- Advice and information (e.g., preparation of energy consultancy, information, thermographic imaging of houses)
- City (e.g., greenhouses on roofs, LED street lighting, construction of photovoltaic noise barriers along a autobahn)
- Energy (e.g., a sewage treatment plant as a hybrid power plant, heat recovery from shower water, geothermal and biomass energy from mine water)
- Housing (such as energetic renovation of houses from the 1950-70s, construction of model houses)
- Mobility (charging infrastructure sites, car sharing of electric cars, fuel-cell powered busses)
- Industry and retail Work (e.g., implementation of solar energy into production processes, carbon neutral gas station and climate neutral retail)

The measures fall into two categories: measures hat municipalities and big organisational actors can take (LED street lightning, hybrid power plants, energy efficient production processes) and measures which requires different choices by consumer (energy passive houses, car sharing of electric vehicles). The energy transition thus requires the cooperation from consumers and business. It also involves important infrastructure issues in the domains of mobility (fast charging points for electric cars) and energy (smart grids, power storage).

7. Differences and interrelationships between the Emscher and Bottrop show case projects

The reconstruction and development of the Emscher river system as well as the Innovation City Bottrop can be interpreted as not only show case projects but also as real-world experiments for developing sustainable solutions for local and regional development. They are learning laboratories about new innovations and forms of cooperation, along with producing tangible results. In this section we will compare the different projects.

Both project relied on positive visions with clearly defined outcomes. The IBA Emscher Park promoted the vision of a clear water flowing in a natural river bed for one the most polluted sewage canals in Europe. Bottrop was based on a vision of halving energy consumption and carbon emissions by increasing the quality of life. Both visions were seen as daring, standing in stark contrast to the negative reality of heavy pollution and unsustainable energy use. Bottrop is a flagship project of the energy transition. It should serve as a reference point about what can achieved through specific innovations, offering lessons about the technology, the usefulness of support action, product imperfections and marketing and distribution. (cf. Kemp et al., 1998).

Both the Emscher Park and Bottrop Innovation City are projects of a local ecological transformation. Big areas are being transformed (or to be transformed) into something more green. They are real-world experiments (learning labs or “lernlabs”) to investigate and show what is possible. Both projects had specific goals and combined a top-down element of guidance with a bottom-up element of getting towards the goals. In terms of the actors as well as the type of projects there are some important differences. The Emscher project draws on an old structure of cooperation between municipalities, through the Regionalverband Ruhr (RVR, Ruhr Regional Association) as well as the Emscher Genossenschaft. The RVR is responsible for regional planning. For almost a century the RVR and its predecessors (SVR and KVR) has been a permanent platform for the cooperation of the different Ruhr communities, while the Emscher Genossenschaft is a cooperative of municipalities for managing water treatment (founded in 1899).

In contrast, the Innovation City Bottrop was initiated to large extent by the Initiativkreis Ruhr (Ruhr Initiative Group). The Initiativkreis Ruhr is an association of 68 companies with a total turnover of € 630 billion and 2.25 million employees worldwide. Established in 1989, it pursues the vision of developing the Ruhr as a strong and attractive location for business. One of the initiatives of the Initiativkreis Ruhr is the Zukunft Ruhr 2030 (Future Ruhr 2030) strategy. The strategy aims at developing the Ruhr area as a “model region for the sustainable solution to global challenges” (Initiativkreis Ruhrgebiet 2007: 35), to be achieved through different types of innovations in the fields of energy, materials and logistics.

Even though the Initiativkreis Ruhrgebiet represents traditionally important actors of the Ruhr area, the institution as such is a “new kid on the block”. Ralf Schüle, the deputy director of the Wuppertal Institute’s research group for energy, transport and climate policy observes that the cooperation model of the Innovation City Ruhr represents an alternative approach to the traditional formal and informal networks. By establishing a set of mainly corporate decision-makers it is to some extent a counter model against the established governance structures, which could limit its chances for success.

Transition projects must be financed, as an area cannot be converted without spending large sums of money. Where did the finance come from? In the Emscher Park financing came from various sources: the municipalities, business actors and the state of NRW. Interestingly, the most important source of funding for the North Rhine-Westphalian structural policies are the EU-Structural Funds. During the period from 2007 until 2013 NRW obtained € 1.3 billion for local development projects in the region. The state government and private donors provide another € 1.2 billion, summing up to a total of € 2.5 billion that will be spent in three priority areas:

- Priority 1: Strengthening the entrepreneurial base – € 500 million.
- Priority 2: Innovation and the knowledge-based economy – € 1.25 billion.
- Priority 3: Sustainable urban and regional development – € 750 million.

The funding activities of the North Rhine-Westphalian energy policies are bundled in the so-called "progress" programme. It offers a wide range of instruments to promote the efficient use of energy and the use of renewable energies in NRW among them solar heating systems, ventilation systems, district heating, combined heat and power generation, biomass facilities, or passive houses. Since 1987 the progress program and its predecessor the REN program funded several thousand projects with a funding volume of more than half a billion €.

For Bottrop we do not have reliable information about money being spent. The overall costs are estimated at €2.8 billion, of which €2.3 billion should come from private partners, 454 million from the EU, the federal and the state government, and €42 million from the city of Bottrop (Drescher 2012). An important difference between the Emscher and Bottrop cases is the scale of transformation. During the Emscher transformation it was possible to address successfully different levels of infrastructure transformation (Wuppertal Institut 2013):

1. Ecological Revitalisation
2. Creation of new spaces for broad participation
3. Improvement of the quality of life
4. Increasing the economic value of the location
5. A new image for the location

The Emscher transformation did mainly address the transformation of public infrastructure (the Emscher river, parks, monuments, sewage systems etc.). It was generally welcomed by the public, because it mainly affected public infrastructure. In contrast, the low-carbon transformation of Bottrop will affect not only public infrastructure, but necessitates the active involvement of private actors and the spending of 2.5 billion euro by those actors. Private actors are known to spend money for private matters (fitting with consumer needs and business profits), not for public matters. Public authorities will spend money for public matters private money. The dependence on private parties (consumers and companies) puts a constraint on Bottrop. Without private parties willing to spend money on energy conservation projects and low-carbon energy systems, Bottrop will not succeed. We should also not expect products requiring lifestyle changes to diffuse quickly.

The energy transition also requires spending from public and private actors. According to the former president of the Wuppertal Institute, Peter Hennicke, the support for the energiewende from the traditional energy sector is only marginal. More than 40% of the money is from private consumers (civil society), who are investing in renewable energy, with the help of government subsidies. Investments by the “Fat Four” (E-ON, RWE, ENBW, Vattenfall) energy utilities in green power generation amounts to just 7%.

In the case of energy it has proven more difficult to enrol industry. Dieter Rehfeld, Head of the research department on Innovation, Space & Culture of the Institute for Work and Technology, observes a general lack of integrated approaches in the energy policy with an explicit management of conflicting objectives in the political discourse.

8. Regional and supra-regional elements

In the transition literature, spatial issues are very much neglected: “Space is only indirectly and implicitly addressed. Both socio-technical regimes and TIS are implicitly understood as footloose cognitive and institutional structures that influence the activities of different actors largely irrespective of their geographical location” (Truffer and Coenen, 2012, p. 6). In the regional development literature, related variety, differentiated knowledge bases and policy platforms (based on relational and collective types of policy arrangements) are considered key aspects behind the creation of new clusters of innovation (Asheim, et al. 2012). More recently, the concept of institutional entrepreneurship emerged as an important factor (Coenen, Benneworth and Truffer, 2012). Institutional entrepreneurship refers to ‘activities of actors who have an interest in particular institutional arrangements and who leverage resources to create new institutions or to transform existing ones’ (Maguire et al., 2004, cited in Coenen et al., 2012).

The Ruhr transition to a green economy is an interesting case of a managed transition in a geographic area. In this section we will examine more deeply the regional dimension as well as its interaction with national and international factors.

In our discussion of energy policies in NRW, we offered details about the innovation and development policies and specific agencies. The regional policies are important but according to Johannes Venjacob of the Wuppertal Institute the energiewende in NRW and Ruhrgebiet is heavily influenced by national decision-making (the phase-out of nuclear power and shift to renewables), . The national energiewende is a conditioning factor in NRW which is traditionally specialized in energy generation, but which is also governed by a coalition of social-democrats and greens, which pursue policy objectives which are highly compatible with the objectives of the national energiewende.

In NRW and particularly in the Ruhr area, regional actors have long collaborated with each other, to create green business, convert an obsolete old industrial landscape into a place for recreation, living and tourism. These changes have been largely led by regional actors, who managed to get federal and EU support for their projects.

Institutional entrepreneurship among municipalities in NRW appears to be a driving factor. The Siedlungsverband Ruhrkohlebezirk and its successor the Regionalverband Ruhr (RVR) played an important role in agenda setting and in implementing and monitoring environmental protection. It organized the system of waste management in the Ruhr area as well as the Emscher Park transformation under the setting of the IBA Emscher Park company and the Emscher Genossenschaft (Emscher cooperative).

In the energy transition, the Ruhr Initiative Group can be viewed an institutional entrepreneur in creating attention to the green energy innovation , in an attempt to position the Ruhr area as a competitive centre for industry, commerce, research and services. Among the flagship initiatives of the group are: Innovation City Bottrop, EffizienzCluster LogistikRuhr (cluster for regional companies in the logistic sector), the RUHR.2010 presentation of the Ruhr as a European Capital of Culture in 2010 and the International School Ruhr.

Also individuals played an important role. Examples of key individuals are SVR's director Sturm Kegel and Willy Brandt, who both managed to put the issue of protecting the human environment on the agenda by highlighting the risk for public health. The Ruhr transition was thus prepared by a concerned regional decision-maker and a charismatic political leader who was able to translate this concern into a positive, concrete vision of a blue sky about the Ruhr. Another influential individual is the Director of the IBA Emscher Park company Karl Ganser. He was not only able to forcefully articulate the vision of a reconstructed Emscher landscape but also was influential in coordinating the financing and implementation projects offering an integrated protection of the cultural and natural heritage of the Ruhr area along the Emscher catchment.

An interesting aspect of the Ruhr transition is that the coal regime plays in some ways a facilitating role. Some low-carbon innovations in the region are based on the legacy of coal mining industry:

- The burning of coal mine methane (CMM) from abandoned mines. CMM has a global warming potential (GWP) 23 times higher than CO_2. Burning CMM thus helps to reduce greenhouse gas emissions compared to not burning it. The burning is done in cogeneration plants. In 1997 the first cogeneration plant converted CMM into electricity and heat. In 2012 148 MW of electricity were produced with CMM cogeneration units (Amprion 2012).
- The use of geothermal heat of mine leachate. At many mine sites, leachate has to be pumped out regularly. In Bochum the geothermal heat of mine leachate is used to provide heat for public buildings.

- Hydro-electric storage in abandoned mines. By 2018, Prosper Haniel Bottrop, the Ruhr area's last operating mine will be decommissioned. Researchers of the Universities of Duisburg-Essen and Bochum have developed plans to use abandoned mines after 2018 as pumped-storage hydroelectric power stations with underground reservoirs. These power plants will serve two purposes. On the one hand, they serve for load balancing the supply of renewable energies. On the other hand, the geothermal energy of the water, which is heated up to 40 degrees will be used for district heating.

Clearly, the coal industry is *not* the driving force behind most green energy and energy saving projects but in some ways the mine heritage allows for the creation of green energy, which is not resisted by the coal and mining actors. Two important drivers behind innovation in green energy are: the strong competence in energy research and *energiewende* NRW. In total more than 750 scientists in several research institutes and 250 companies in the Ruhr area work on energy supply, power control and power plant construction[5]. A prominent example of the Ruhr's energy competence is the ef.Ruhr. The ef.Ruhr[6] (Energieforschung Ruhr GmbH) is Germany's largest association of research chairs in the field of energy. More than forty professors of the universities of Bochum, Dortmund and Duisburg-Essen cover the entire spectrum of energy technology. They closely cooperate with global business players of the region such as E.ON, RWE and Evonik. Focal areas of ef.Ruhr is research for reducing CO_2 emissions in the power generation, CO_2 transport and storage, in particular Carbon Capture and Storage (CCS) as well as solutions for upgrading coal plants with CO_2 capture. The solutions developed include a mobile plant for CO_2 capture from flue gases, which won in 2008 the "Hightech.NRW" contest.

A last facilitating regional factor is regional identity. Even though the Ruhr area was never a federal state (land) on its own there was always a dominating sentiment of pride related to the industrial power of the region. This was on the one hand based on the central role of the Ruhr area for the industrial development of Germany. The economic crisis and decline led local authorities to do something: to economically and ecologically revitalise an area with a history they took pride in. It spurred actors to mobilize the remaining resources and competences of the region. There was also an element of pride by turning the disadvantages of the region such as the highly polluted Emscher into a showcase of ecological modernisation, exemplified in the 10 year long exhibition (IBA) Emscher park.

At the end of the section we turn to the interlinkages between the green business and nature conservation project, the ecological reconstruction project and green energy transition project in the Ruhr area and NRW. Each of the projects started at a different time and had different aims. There is no

[5] For more information visit http://www.ruhrenergy.de.

[6] For more information visit http://www.efruhr.de.

simple causality from „blue sky“ to „blue water“ to „green energy“. They are all part oft the ecological modernisation process, coupled with the belief that dealing with ecological problems creates economic opportunities.

Local authorities responded to problems of pollution, depopulation and the loss of jobs in coal mining and steel as an important background factor. Citizen concerns and national policies were an important background factor too. Important policy decisions were taken up by parliament. Flagship projects and investments in education and research also helped to make the transition from dirty industry to a green industry in a greener landscape. The way in which the different transitions are related to or even build on each other is a topic for deeper analysis and what will be discussed in further workshop with experts and stakeholders.

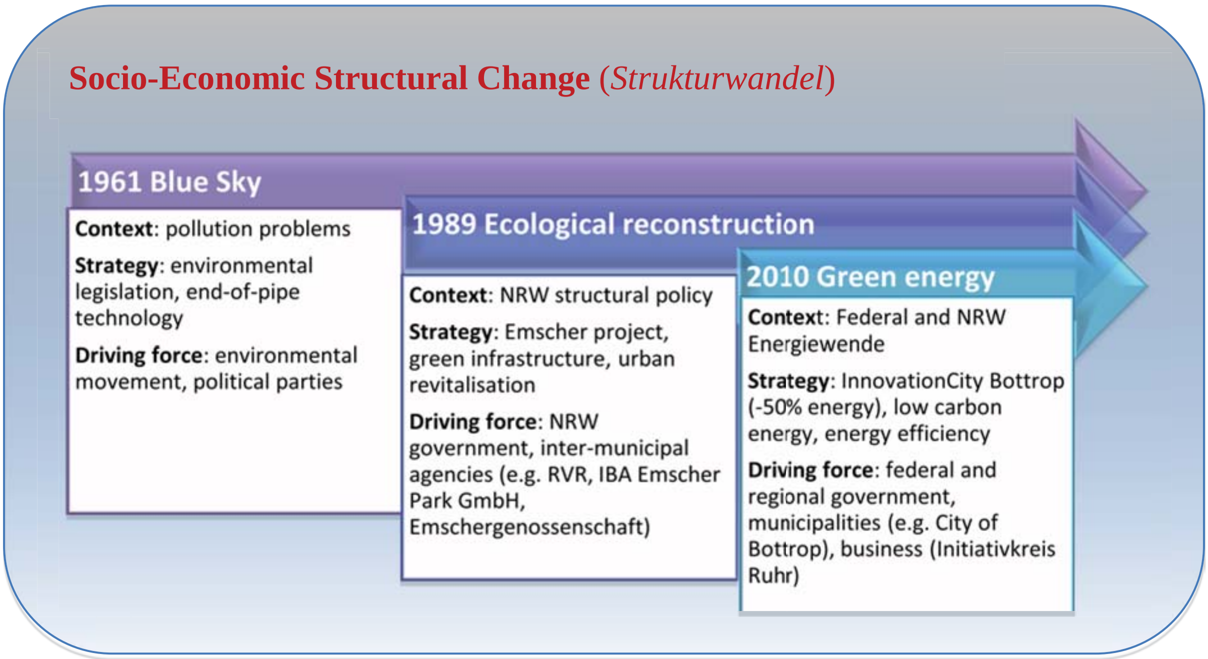

Figure 1: Main phases and elements of NRW sustainability transition

9. The lessons for transition management

The Ruhr area has been in transition for four decades, ever since the decline of the steel and coal industries, which was associated with major job losses. The area has been revitalised thanks to the investments in the clean-up and projects such as the Emscher Landscape Park. The analysis of the economic development agency for the Ruhr area WMR established that the region obtained economic strengths in resource efficiency and sustainable consumption, as lead markets[7]. In the Ruhr area, the lead market Resource efficiency constitutes 6.2% of the regional economy, which is considerably above the share for Germany (3.6%) and the state of NRW (3.9%) (see section 4). The strong energy sector is well placed to take advantage of the growth potentials for renewable energy and energy efficiency created by the national and regional energiewende goals and programmes. None of the transitions is finished: the share of coal is still higher than the share of renewable and cities are getting depopulated. Since 1960, the Ruhrgebiet has 600,000 fewer inhabitants. The city of Essen has now 140,000 less inhabitants (LIT NRW 2013).

It is interesting to investigate the Ruhr transition processes from the point of view of transition management. Many of the elements of model of transition management as developed by Rotmans, Loorbach and Kemp (Rotmans et al., 2001, Loorbach, 2007, Kemp et al., 2007, Rotmans and Loorbach, 2010), are being confirmed by the eco-restructuring of the Ruhr area: the importance of an inspiring and concrete vision which is shared by most actors, platforms for strategic thinking, special innovation projects acting as stepping stones for transition processes, and special transition institutions. Different agendas are being aligned by institutional entrepreneurs: improving air quality for health reasons, environmental amenities, preserving industrial heritage, improving the quality of places, keeping labour in the Ruhrgebiet and stopping depopulation. The story also underlines the importance of transition showcases that speak to the imagination and identity of people. It confirms what has been said about real-world experiments: that they help to "build a constituency behind a product - of firms, researchers, public authorities - whose semi-coordinated actions are necessary to bring about a substantial shift in interconnected technologies and practices"(Kemp et al., 1998).

The proximity of cooperative actors in the state of NRW is considered by us a major reason for the success of the eco-transition. Where national policies are usually fighting each other over ministerial policy choices with little regard to policy coherence, regional actors and city governments are more cooperative and more oriented towards achieving results on the ground. Despite setbacks and conflicts there has been a long period of cooperation in the Ruhr. Different from what is predicted by transition

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[7] A lead market is a regional market that is first to adopt a global innovation design, thanks to a demand advantage, a price advantage, an export advantage, a transfer advantage and/or a market structure advantage (according to Beise at http://www.rieb.kobe-u.ac.jp/academic/ra/dp/English/dp141.pdf). In NRW and Germany, Resource efficiency and Sustainable consumption obtained the official status of a lead market.

theory, the old regime of coal mining and heavy industry played a facilitating role: technical knowledge about pollution and waste helped to establish environmental technology businesses in the NRW area, abandoned quarries were used for storage for renewables and more than in other states power companies in NRW can take advantage of the regional energy cluster to promote green power. A decisive factor (unique for Europe, but similar to China) is that in Germany, state authorities are responsible for innovation policy, much more than national authorities, leading to and fostering regional specialization.

The ecological restructuring of the landscape in the Ruhr areas and the energy transition project to sustainable energy use in NRW have top-down elements as well as a bottom-up elements. The top-down elements consists of a clear sense of direction and making available money for transition projects. Interestingly, the largest funder of the ecological restructuring projects is the European Commission through its Structural funds.

The Ruhr transition consisted of a three waves of change, which in some ways build on each other:

1. The greening of dirty industries through pollution control and policies for nature conservation which helped to establish an eco-industry (1961-1990)
2. The ecological reconstruction, clean-up and urban revitalization of the Ruhr area (1989-2015)
3. The sustainable energy transition (2010 onwards)

Interestingly, the transition frame served as a frame even when the word transition was not used. The overarching transition is the socio-economic strukturwandel (structural change) due to the decline of heavy industries. This coincided with growing environmental awareness by citizens and politicians, and the succeeding implementation of environmental protection. The phase of agenda setting and introduction of pollution control and nature conservation started in 1961 with Willy Brandt's promise of a blue sky above the Ruhr.

This phase was followed by a (partly overlapping) phase of ecological reconstruction, clean-up and urban revitalization of the Ruhr area, which was marked by the start of the IBA Emscher Park in 1989. In 2010 a third transition process began: the transition to sustainable energy. The sustainable energy transition is supported by NRW and national energy transition programmes and regional innovation policies of which the Innovation City Ruhr contest is an example.

The Ruhr area transformed against the background of wider economic and political developments. Relevant developments for the low-carbon energy transition are the prices of fossil fuels, the European Emission Trading system for carbon allowances (of which prices are temporarily low) and German obligations under the International Convention on Climate Change (ICCC).

The eco-restructuring of the Ruhr area presents a remarkable case of a managed transition, bringing out the importance of regional actors and factors, alongside external stimuli. It is a case of ecological modernisation, a concept born in Germany which later became a term for social theory, showing that discourse, action and analysis are related to each other. The transition concept helps to make sense of specific processes of change and draws the attention to interaction effects. The politics of the (sociotechnical) processes require deeper analysis which we plan to undertake in the next few months. There also is a unique German element in the Ruhr transition, but at this moment it is hard to say exactly what this consists of. Comparative analysis may be needed to uncover this. Our paper offers nothing more than a first attempt at analysing the Ruhr transition.

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Appendix: Overview of meetings with stakeholders involved in the review of information about the Ruhr transition

This paper is based on interaction with major stakeholders of the Ruhr area, as well as the review of various internet sources. The information was compiled in cooperation with central regional stakeholders such as the Emschergenossenschaft/Lippeverband (EG/LV), Regionalverband Ruhr (RVR), Wirtschaftsförderung Ruhr (wmr), the Landesamt für Natur, Umwelt und Verbraucherschutz NRW (LANUV) as well as representatives of the cities of Bochum and Essen. The information was presented and discussed in a sequence of conferences and workshops with governmental and non-governmental stakeholders of the Ruhr area, involving the following individuals:

4.6.2012 at the Wuppertal Institute:

Participants: Dr. Wolfgang Beckröge (RVR), Mrs Trenk (RVR), Mrs Herzberg (City of Bochum), Mr Mühlenkamp (City of Essen), Mrs Siepmann (City of Essen)

14.6.2012 at the RVR Essen

Participants: Dr. Beckröge (RVR), Mrs Trenk (RVR), Mrs Snowdon (RVR), Mr Fölster (City of Essen), Mr Hartwig (City of Bochum), Mr Herzberg (City of Bochum), Mr Höing (City of Dortmund), Mr Mühlenkamp (City of Essen), Mrs Siepmann (City of Essen).

25.7.2012 at the RVR Essen

Participants:

Prof. Dr. Finke, Mr Gendries (RWW), Mrs Heinemann (City of Bottrop), Mr Höing (City of Dortmund), Mr Jäger (wmr), Mrs Mann (RVR), Mr Mühlenkamp (City of Essen), Prof. Dr. Oldengott (EG/LV), Dr. Reuter (Landesarbeitsgemeinschaft Agenda 21 NRW), Mrs Semrau (EG/LV), Mrs Snowdon (RVR), Dr. Sommerhäuser (EG/LV), Mrs Raskob (Councillor City of Essen)

We thank the stakeholders for their time and willingness to discuss with us critical events, projects and developments, with special attention to the stakeholder considerations between important projects of the transition of the Ruhrarea. For the organisation of this process and contributions to improving the text we would like to thank Prof. Dr. Oscar Reutter and Miriam Müller at the Wuppertal Institute. We are also grateful for contributions from Mrs Trenk, Mrs Snowdon and Dr. Beckröge of the Regionalverband Ruhr.

Submission No. 247

Metering motorbike mobility: informal transport in transition?

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Abstract: The majority of urban dwellers in rapidly developing cities throughout the world depend on so-called informal transport services for their mobility needs. Thus far the field of transition studies has dealt with the dynamics of sociotechnical change in situations where regimes of automobility and sanctioned public transport constitute the dominant order, but less so in situations where informal transport paratransit thrive. Vast in scope and size, these systems can be conceived of as a ubiquitous third sub-regime with their own distinct set of coordinating principles, operational routines, user practices and industry structures. To enquire about the forces of stability and prospects for sociotechnical change concerning these kinds of systems, we follow the evolution of Bangkok's illicit motorcycle taxi regime including an analysis of recent experimental efforts to introduce a potentially disruptive innovation, i.e. a portable ICT platform used as taximeter.

Keywords: transitions; sociotechnical experiments; informal transport; motorcycle taxis; Bangkok

1. Introduction: a forgotten mobility segment

The majority of urban dwellers in rapidly developing cities throughout the world depend on so-called *informal transport* services for their mobility needs[1]. Essential services to growing urban populations are provided by illicit operators of small paratransit-type vehicles, such as *bekaks* (pedicabs in

1 The term 'informal transport' is used throughout this paper as way to talk about paratransit systems, which are organized in informal/illicit ways. These kinds of systems are known by many different names. Cervero (1991, 2000, 2001) coined both the terms 'informal transport' and 'informal entrepreneurial transit'. Kumar and Barrett (2008) place these informal systems more firmly within the broader domain of public transport. They refer to 'non-conventional informal public transport services' and discursively sets it apart from 'organized formal public transport services'. Ocampo (1982) refers to 'low-cost transport' because these informal systems are usually operated and used by the lower-income strata of the population. Fouracre and Maunder (1979) refer to the notion of 'intermediate public transport' to connote the transport modes which provide a service between that of a taxi and a conventional bus. Gwilliam (2002) refers to 'small vehicle transit' and stresses the potential of mobilizing the flexibility of smaller vehicles. The term 'paratransit' (initially coined by Kirby et al. 1974) is often used to refer to the way these systems operate. In its broad meaning, the term connotes any transit that uses the same infrastructure (roads, bus-lanes etc) and simply exists besides ('para') conventional public transport (taken to mean large sanctioned public transport vehicles such as busses and trains).

Jakarta), *okadas* (motorcycle taxis in Lagos), *mishuks* (motorized three-wheelers in Dhaka), *kombis* (minivans in Johannesburg), *jeepneys* (extended US army jeeps used as busses in Manila) and many more. As the backbone of many a city's system of transport provision and as a crucial pillar of a much larger informal economy, this kind of unregulated transport provision accounts for around 15 percent of the total employment in many developing world cities (Cervero, 2000). Without these mobility operators and their ramshackle vehicles, most of these cities would simply grind to a halt. Far from being in decline, informal transport modes are on the rise during these times of relentless urbanization, rapid modernization and economic growth in the Global South. Nonetheless, many local governments do not (want to) fully recognize the key-role of these systems of transport. As a result, scores of mobility operators are forced to 'ply their trade illicitly' in a situation where governments merely tolerate the existence of their operation at the margins of society (Cervero and Golub, 2007).

For researchers interested in urban transformations, sociotechnical transitions and sustainable innovation journeys, the proliferation of these informal transport systems may instigate a whole new research agenda. Are concentrated efforts to introduce new technologies possible for systems at the margin, which are not on the receiving end of government support or funding, but on the receiving end of government scorn and repression? How should we conceive of these systems in the wider context of urban mobility, sustainability, and sustaining urban mobility? Is the provision of transport by many small – often old and polluting – vehicles a carbon-inefficient way to move millions and a barrier for city governments to implement 'proper' CO2-saving large-scale public transport systems? Or are these informal systems a form of locally rooted appropriate technology to be encouraged and applauded as possibly giving rise to alternative pathways to social and environmental sustainability? Is there no viable future for these systems in this era of globalization and are they destined to 'die out' as developing world cities modernize? Or will these kinds of transport systems continue to grow and flourish in developing world cities and, perhaps, expand to find a place in first-world cities?

A promising way to start addressing such questions is to combine insights from two academic fields: transport studies and transitions studies. In the transport studies literature informally organized systems of urban transport do not feature prominently, but some comprehensive accounts have been published (Ocampo, 1982; Takyi, 1990; Cervero, 2000; Goddard, 2004; Gwilliam, 2005; Cervero and Golub, 2007; Kumar and Barret, 2008; Rifai et al., 2011). However, these accounts are concerned with the operation and regulation of these systems and not with their evolution and the prospects for change. In the field of transition studies, on the other hand, these evolutionary sociotechnical dynamics are the primary object of enquiry and to analyze the forces of stability and the dynamics of change a number of analytical frameworks and perspectives have been introduced (for an overview see Grin et al., 2010; Markard et al., 2012). Through the lens provided by one of the field's key frameworks, *the Multi-level Perspective* (Rip and Kemp, 1998; Geels 2002), transitions are described as shifts in sociotechnical systems brought about by the interactions at three levels: regime ('rules' and 'grammar' embedded in institutions and infrastructures of incumbent socio-technical systems that fulfill a societal function such as mobility); landscape (the exogenous structural backdrop constituted by long-term trends, sometimes disrupted by major events); and niche (protective spaces for an emerging configuration as an alternative way of fulfilling a societal function). The emergence of novel practices at the niche level takes shape through conducting *experiments* as real-time representations of possible futures. Previous comprehensive accounts on mobility transitions and experiments (Kemp et al., 1998; Hoogma et al., 2002; Geels, 2005; Van der Laak et al., 2007; Van den Bergh, 2007; Geels et al.; 2012), dealt with these dynamics in situations where regimes of automobility and sanctioned public transport constitute the dominant order, but not in situations where systems of informal transport thrive. Thus far, the forces of stability (regime dynamics) and the prospects for change (embodied in niche experiments) for these illicit sociotechnical systems remains unexplored territory.

To begin to address this gap, we explore what kinds of experiments are being conducted and develop new interpretations of these efforts in the wider context of evolving urban transport systems. To do so, we follow the evolution and the emergence of novel practices for one specific tangible system: Bangkok's motorcycle taxies. The experiment we focus on is the introduction of a new ICT platform that allows metering motorcycle taxi trips. As a specific research question, we ask: *How did the introduction of the motorcycle taxi meter evolve in the context of the Bangkok motorcycle taxi regime and what implications can be drawn for the study of mobility transitions?*

The remainder of this paper is structured as follows: section 2 elaborates on the notion of informal transport and conceives of its relation to regimes of individual private transport and sanctioned public transport. Section 3 elaborates on the notion of experimentation and takes stock of a number of approaches and contributions from the transition studies literature. It also compares a number of mobility experiments in informal settings in Asia with a number of mobility experiments in Europe. Section 4 constitutes the case about motorcycle taxis in Bangkok including a discussion of the methodological approach. Section 5 concludes.

2. Conceiving of informal transport

Most authorities in developing cities throughout the world can scarcely grapple with the rapid expansive growth and massive influx of new urban dwellers. They can barely maintain the existing transport services, let alone plan for expansion in order to come to terms with the increasing demand for transit (Kumar and Barrett, 2008). As a result, diverse arrays of unregulated transport systems have organically sprung up without any centrally coordinated plan. Informal transport thus refers to transport services available for communal- or public use, but which are not sanctioned by the public sector. The term 'informal' best reflects this situation: casually disguised by lack of supervision and hidden in the background of both the officially sanctioned public sector and the registered/formal market economy.

Informal transport modes are *gap-fillers*. Mostly constituted by small vehicles they literally fill the physical gaps in road space left vacant between larger cumbersome vehicles in many gridlocked developing world cities. They also fill the functional gap in public transit coverage where governments fail to provide. Even in cities where governments do provide for adequate public transport, the informal systems still play crucially important roles in patching large scale formal public transport together by acting as feeder modes and by providing for short trips as the crucial last mile in many a journey. As a form of ‘intermediate transport’ (Fouracre and Maunder, 1979) they fill the gap between the public bus and the private automobile or motorcycle. As a form of ‘low-cost transport’ (Ocampo, 1982) they fill socio-economic gaps by providing job opportunities for those at bottom in situations where marginalized informal mobility operators work in gritty interstitial spaces and ‘live in the cracks’ of urban society.[2] Finally, they allegedly fill a temporal gap. Associated with traditional society and as a prevalent phenomenon in developing cities and not in first-world cities, some argue they are characteristic only for a certain ‘stage of development’ (Rostow, 1960). By this rationale, they are ephemeral systems serving as a mere temporary fix to cope with rapid urban growth. Many development economists indeed maintain that urban informality and the brunt of informal economic activities will disappear over time as an inherent part of growth and development (Straub, 2005; La Porta and Scheifer, 2008)[3]. We maintain that it is certainly conceivable, even plausible, that informal transport systems will not be a mere temporary phenomenon, but that they will remain an integral part of the urban fabric in most developing cities as part of alternative trajectories to modernity.

The term *paratransit* is often used to refer to the way informal transport systems operate: flexible demand-responsive small-vehicle transport configurations, which can be viewed as a neglected third way besides mass transit (based on central planning and schedules) and individual motorized transport (based on private vehicle ownership). In the US and Europe paratransit modes are selected against through various forms of regulation, but small numbers persist in specialized niches, such as transport provision for the elderly and the disabled. In developing world cities, however, paratransit is omnipresent. A bewildering array of small locally adapted vehicles – serving as flexible busses and (shared) taxis – occupy an incredibly wide range of market niches not catered for by formally sanctioned public transport. The ‘transport ecosystem’ - constituted by the urban form and the transport modes that populate it - in these cities is more richly diverse because of the addition of these informal systems.

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2 The phrase ‘living in the cracks’ is borrowed from anthropologist Claudio Sopranzetti, who has extensively studied Bangkok’s motorcycle taxi drivers and their involvement in politics. As he puts it: “*Motorcycle taxis are in the cracks of many things. This being in the cracks is both physical and metaphorical. Look at their movements inside traffic: they make space where there is no space. They move in the cracks both within traffic and within society. They move in between classes, in between buildings, in between cars… Motorcycle taxis live in the cracks of Thai society*” (New Mandala, 2010)

3 Informality is also back on the agenda of urban planning and international development (Roy 2005). As the study of ‘places’ – locations imbued with power and meaning (Cresswel 2004) - the discipline of human geography in the context of urban planning has focused on informality related to sedentary aspects of the human condition of people as city dwellers. Most of these studies focus on informal settlements (for examples from Bangkok see for example Herfeld, 2006; Dovey and King, 2011). However, far less attention has been paid to the study of mobility – the dynamic equivalent of place (Cresswell, 2006) – and informality.

Previous analyses of land-based passenger transport in Europe or North-America revealed two prevalent, but highly distinct, sub-regimes: individual private transport (mostly based on the steel and petroleum private-car) and public/collective transport (Kemp and Simon, 2001; Hoogma et al., 2002; Geels et al., 2011). Table 1 characterizes informal transport as a third pervasive sub-regime based on a distinctively different set of guiding principles, technologies, industrial structure, user relations and markets, policy and regulations, knowledge and culture (Smith, 2007).

Table 1. Contrasting sub-regimes of urban passenger transport in developing cities[4]

Socio-technical dimension	Regime of individual private transport	Regime of informal transport	Regime of sanctioned public transport
1. Guiding principles	Centrally planned infrastructure provision based on the 'predict and provide' principle. Freedom for the driver-passenger as desires and whims of the operator-passenger are paramount	Bottom-up distributed operational coordination; self-organizing systems for which no dedicated infrastructure is provided; they operate onto existing infrastructure as a form of 'paratransit'	Centrally planned infrastructure provision; sometimes dedicated infrastructure such as rail tracks or bus lanes; central top-down operational coordination; fixed routes and time schedules
2. Technologies	Small homogenized vehicles, assisted by ICTs such as navigation devices based on distributed intelligence	Plethora of locally adapted divergent small/medium sized low-capacity old-fashioned re-worked vehicles, not assisted by powerful ICTs, but by 'human infrastructure' as part of a large socio-spatial system	Large cumbersome homogenized high-capacity passenger vehicles for rigid use on rail and road, assisted by powerful ICTs as part of a large technological system
3. Industrial structure	A commodity (homogenized vehicles produced by large TNC's sold on the global marketplace)	A service provided by the informal sector (vehicles locally adapted and re-worked to be sold or rented out by local traders)	A service provided by the formal sector (vehicles as specialized commodities sold by TNC's on the global marketplace to local governments or registered businesses)
4. User relations and markets	Homogenized vehicles for private individual use resulting in active operator-users	Communal use as taxi-like or flexible bus-like modes with ultra responsive operators; free enterprise (laissez faire, 'war over the penny') situation resulting in choice for passengers-users who sometimes have to 'haggle' for a fare	High capacity corridors based on plying fixed routes, time schedules and calculated prices resulting in passive passenger-users
5. Policy and regulations	General rules of the road, 'predict and provide' principles, powerful lobbying coalitions to retain	Unregulated/self-regulated, rule of law not paramount, de-facto overlordship and rent seeking by	Regulated, Officially sanctioned services provided by the state or provided by the private sector

4 Many transport modes / mobilities do not neatly fit into one of these three boxes. As pointed out by Sheller and Urry (2006b, p.1) simplified categories of 'private' versus 'public' in the context of mobility systems are deeply problematic ("*this divide may need relegation to the dustbin of history*"). There are similar issues for simplified categories of formal/sanctioned public transport versus informal transport. Formal versus informal is by no means a dichotomy, but a spectrum between the extremes of informal transport (completely illegal, on the receiving end of government repression and marked by flexible paratransit-like operation) versus fully sanctioned public transport (completely legal, on the receiving end of government funding or licensed concessions and rigid fixed route based operation). Nonetheless this categorization enables a way to engage with the practices and socialities of a range of transport systems, which transition researchers have so far neglected.

	unrestrained motorization	local strongmen	through concessioning
6. Knowledge	Globalized expert knowledge associated with predict and provide principles and planning for the car	Indigenous locally adaptive knowledge (‘makeshift’, ‘the power of context’)	Globalized expert knowledge based on infrastructural planning and capacity calculations
7. Culture	Modern individualized society	Traditional society (non-modern and marginalized)	Modern planned society

3. Sociotechnical experimentation in informal transport

Sustainability transitions are extensive transformations in the way societal functions, such as transportation, are fulfilled which do not only involve technological changes, but also changes in user practices, regulation, industrial networks, infrastructure, symbolic meaning and value systems in response to persistent societal problems (Geels, 2002; Grin et al., 2010). This implies the study of both the forces of stability and the dynamics of change in sociotechnical systems. As the locus of radical change, experimentation with alternatives has been demonstrated to play a key role at the early stages of transitions (Kemp et al., 1998; Raven and Geels, 2010; Berkhout et al., 2010). *Experiments* represent embodied innovation in the form of small-scale tangible initiatives to test a particular kind of novel, allegedly more sustainable, sociotechnical configuration in real-life use. In these ‘hands-on projects’ (Schot and Geels, 2008) technological expectations materialize as real-time representations of future technological situations (Borup et al., 2006). Through experimentation and the construction of protected spaces around an innovation, sufficient momentum can induce a transformation of an incumbent sociotechnical regime (Kemp et al., 1998; Ulmanen et al., 2009; Smith and Raven, 2012). Thus conducting experiments can be viewed as a way to explore, to learn, to reflect and to build a coalition around an innovation to help enact a certain range of envisioned possible futures for informal transport.

A number of analytical (overlapping) approaches have emerged around the notion of experimentation in the context of sociotechnical transitions.[5] *Strategic Niche Management (SNM)* is an analytical tool and governance approach that is firmly embedded in the overarching multi-level perspective (MLP) on sociotechnical change (Kemp et al., 1998; Raven, 2006; Schot and Geels, 2008). Mobility experiments have been core objects of enquiry from the outset in several of these SNM-related approaches (e.g. Harms and Truffer, 1998; Hoogma et al., 2002; Brown et al., 2003; Van der Laak et al., 2007; Van den Bosch, 2010). These examples have thus far focused on innovative mobility practices in the confines

5 Varieties include ‘bounded sociotechnical experiments’ emphasizing the process of social learning (Brown et al., 2003; Vergragt and Brown, 2007; Brown and Vergragt, 2008), ‘transition experiments’ starting from a societal objective as opposed to a technological innovation (Van den Bosch and Rotmans, 2008; Van de Bosch 2010), ‘grassroots experiments’ emphasizing civil society activities as opposed to SNM’s initial business focus (Seyfang and Smith, 2007) and ‘sustainability experiments’ emphasizing the need to focus on the innovative capabilities within emerging Asia as way to avoid environmental convergence (Berkhout et al., 2010). The applicability of SNM-related concepts and processes to describe and analyze such a wide range of different technological- and institutional settings suggests that the approach is a promising perspective to investigate potential experimental efforts in the domain of informal transport.

of Western-Europe and the proliferation and scope for change in the vast informal transport systems of developing world cities remains unchartered territory.

The governing principles conducive for setting up planned sociotechnical experimentation, and the institutional capacities necessary to create and maintain protective spaces to shield these innovations from mainstream market selection, would seem to be lacking in the informal settings of developing cities. After all, "*…the hallmark of informal entrepreneurial transit is open competition. Services are designed and priced to satisfy customers. Operators receive no subsidies or capital assistance … it is about as close to laissez-faire transportation as you can find*" (Cervero, 2001, p.16). Furthermore, most developing city governments seek to convey a first-world city image and tend to favor large-scale high-tech modern formal systems (like elevated highways, monorail tracks and sub-way systems). They sometimes seek to actively ban - or at the very least they are reluctant to engage with - informal systems associated with traditional society, ramshackle vehicles and an air of non-modern low-tech backwardness. Therefore, purposely guided and planned hands-on initiatives, introducing new technologies not yet ready for the market, could be expected to be a far cry in these informal settings.

Much evidence, however, points to the contrary. In fact, there are many ongoing experiments to facilitate the introduction of highly novel technologies and practices geared towards reconfiguring existing informal mobility configurations. But most of this goes largely unnoticed, 'below the radar' so to speak (Kaplinsky, 2011). As of yet, these kinds of mobility experiments are not documented in detail or scrutinized in the academic literature. Recently documented examples from Asia on websites and blogs include: the introduction of electric tricycle taxis as part of an effort to improve the air quality in Manila (Environment News Service, 2011); a pilot project to demonstrate the perks of an intelligent transport system based on auto-rickshaws to boost transit efficiency during the Commonwealth games in New Delhi (Stadium, 2012); a new business model by a startup company acting as a middle-man between professionalized motorcycle taxi drivers and customers by providing services to maintain mobility and avoid being stuck in the traffic jams of Jakarta (Time Magazine, 2012); a public trial with an ICT platform serving as a taximeter for the incredibly large motorcycle taxi market in permanently gridlocked Bangkok (Fast Company, 2011).

The context of Asian megacities, in which these informal transport experiments are situated, differ substantially from Western Europe as the setting for mobility experiments previously studied with SNM and related approaches. In their struggle to move millions of – mostly poor – residents the rapidly growing densely populated megacities in Asia give rise to differently composed land-use and mobility systems. These Asian megacities face different sustainability related challenges with less funding and capabilities at their disposal to address these issues. Just maintaining the everyday movement of the increasing numbers of urban dwellers is a daunting task. Moreover, in many cities the proliferation of informal transport systems is deeply linked to the presence of historically disadvantaged groups of people and the influx of poor rural dwellers. Rickshaw pullers in Kolkata, for example, are mostly from poor Bihar or Bangladesh. The emergence and proliferation of a minibus taxi system in Johannesburg could be viewed as one of the legacies of apartheid. Nevertheless, these systems provide job opportunities and livelihoods for marginalized urban dwellers, which is a key priority for those promoting sustainable development in the developing world.

Much like in European mobility experiments, the informal transport experiments are specifically framed under the banners of 'green growth' and 'social entrepreneurship' and as an integral part of an agenda for economic growth. These experiments aim to introduce monitoring, mapping, quantifying, professionalizing, efficiency improvements and other modernist elements to 'repair' incumbent informal transport systems, which are generally perceived as traditional/non-modern. As such the introduction of new technology, novel business models and other strategic work by the actors involved to propel paratransit systems into the 21st century can be viewed as geared towards opening up alternative pathways to modernize urban transport systems, which have mostly seized to exist in Europe and the Western world in general. In European cities paratransit modes mostly faded out of existence in favor of sanctioned large-scale public transport systems and individual (motorized, car-based) transport. This potential alternative pathway for modernizing Asian cities, on the other hand, entails the continued dominance of informal transport through modernized paratransit systems as an integral part of these future cityscapes.

4. Bangkok's motorcycle taxis

4.1. Methodological approach

We explore the forces of stability and the prospects for change for the motorcycle taxi industry in Bangkok through an in-depth analysis of one experiment in particular: a meter for motorcycle taxis. Inspired by qualitative methodological approaches for geographers (Limb and Dwyer, 2001; Crang and Cook, 2007), we employ process theory (Van de Ven and Poole, 1995; Pettigrew, 1997) as an explanatory narrative style for the analysis of this longitudinal embedded single case study (Eisenhardt, 1989; Yin, 2003). The analysis is based on site visits and stakeholder interviews conducted as part of ethnographic fieldwork about a broader range of topics related to the prospects for sustainable change for urban transport systems in Bangkok and other Thai cities. The empirical material for this analysis was collected during a two-week and a subsequent two-and-a-half-month field visit between February and June 2012[6] complemented with additional desk research.

A key-source of data is 45 semi-structured in-depth interviews with a diverse array of knowledgeable stakeholders (policy officers, transport studies scholars, transport consultants, transport safety experts,

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6 Upon commencing the fieldwork the actual experiment had been finished for two months and the implications and lessons learned were becoming clear. In line with many previous SNM studies, we studied the experiment 'ex-post' and information about the actual experiment is drawn from participant interviews and secondary sources they brought to table (such as pictures, movie clips and unpublished written accounts) and desk research.

entrepreneurs, taxi drivers and more - a quote from ‘interview n’ is referred to as ‘Int. n’). The Multi-level Perspective and the Strategic Niche Management approach initially informed the interview questions, but there was substantial room for interviewees to bring in their own topics. In several cases initial interviews turned into more lengthy engagements through half or full-day site visits. Echoing John Urry’s (2007, p. 39) call for employing varied ‘mobile methods’, this allowed direct observation and engagement with motorcyclists and other actors by travelling as an investigating participant through the socio-technical system under study (an ethnographic engagement or ‘observation n’ - e.g. a casual conversation with a driver, taking pictures at a street rally, a stakeholder presenting an unpublished report - is referred to as ‘Obs. n’).

The interviews and observations were complemented with content analysis of documents that reported specifically about the motorcycle taxies in Bangkok at various points in time or voiced expectations about the plans for the metering experiment. These documents were drawn from a wide range of sources: expert media, such as journal articles (e.g. Cervero and Golub, 2007; Oshima et al., 2007), reports (e.g. Poapongsakorn, 1994; Cervero, 2000; DLT, 2006; Kanjanapanyakom, 2010) and general audience media, such as newspaper articles (e.g. Bangkok Post, The Nation, Phuket Gazette), press releases (e.g. AFP, Business Press 24, Marketwire) and blogs (e.g. 2Bangkok, New Mandala, The Economist, Wired, Times, All About Bikes Magazine, Fast Company, The City Fix, Guerilla Stock Trading). Together, this wide array of sources serves as the input for this case study upon which our narrative is based.

Stakeholder claims and other documented accounts concerning Bangkok’s motorcycle taxis were first coded in three broad categories reflecting the three levels of the multi-level perspective: 1) references to major long-term trends and disruptive events that punctuated these trends in relation to motor-cycle taxis in Bangkok (landscape); 2) references to the practices concerning present day operation and ways in which day-to-day operation changed over time from inception up to the present day (regime) and; 3) the advent of novel practices and innovations through tangible experiments as a way to enquire about possible futures conceived of for the motorcycle taxi in Bangkok (niche experiments).[7] The latter category was coded in more detail using key niche-development categories of ‘actors and networks’, ‘expectations’ and ‘learning’. The coded material was then used for drafting histories of the Bangkok’s motorcycle taxi regime and the inception and execution of the niche experiment with the taxi-motorcycle meter. The long-term site-visit allowed for continues feedback loops between collecting

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7 In our efforts to describe the motorcycle taxi regime we opted for a practice-based operationalisation of regimes. In this light, we study transitions by analyzing how new practices emerge, stabilize and replace previously established practices. Despite potential ontological incompatbilities between the clearly structured levels of the MLP and the relationist flat-world ontology of social practice theory (see Shove and Walker, 2010; Geels, 2011), we employ this combination to describe some of the intricacies of this informal system from within in order to unravel part its informal hierarchies, politics and complexities of this illicit sociotechnical system, but we implicitly retain the MLP levels in our thinking both as a way to interpret these practices in a wider societal context and as a rhetorical device to structure the narrative.

evidence, coding, interpretation, drafting histories and new engagements with stakeholders and interviewees.

4.2. Formalizing the informal: a multi-level analysis

The motorcycle taxi (*motorcy rub jang*; literally ‘hired motorcycle’) occupies a crucial position within Bangkok’s transport ecosystem as a feeder mode that processes passengers in fruitful exchange with the other transport modes. Every day around 200.000 motorcycle taxi drivers operate in Bangkok’s gritty alleys and streets alone, which is approaching the total number of taxi drives in the whole of the USA (239.000 in 2012). They play an important role in tying together the city’s widely diverse collection of transport systems. In recent years the soaring motor taxi ranks grew faster than any other transport mode in Bangkok.

A number of long-term landscape trends related to economic growth, regional inequality and the lack of urban planning underlie the spectacular growth of this mundane yet remarkable phenomenon. Decades of economic growth and planning for the car have rendered densely populated Bangkok one of the most grid-locked megacities in the world with traffic jams of legendary proportions since the early 1990’s. So-called superblocks and a general fishbone shaped road layout constitute the urban landscape (also see Sintusingha, 2006). Most locations can only be accessed via long narrow side roads (*soi*), which emerged without any central planning. It is virtually impossible to serve these thin winding alleyways by any public transport mode besides small vehicle paratransit. The motorcycle taxi can adequately navigate traffic jams and narrow alleys in order to meet the increased demand for movement better than any other mode (Obs. 2; Obs. 63).

During these times of economic growth and rapid modernization in Thailand, the disparity of wealth between urban areas and rural areas – particularly between the primate city of Bangkok and the rest of Thailand – has increased (Pholpirul, 2011). Consequently, the large reservoir of readily available cheap labor from the Thai countryside, especially from the poor north-eastern provinces (*Isan*), opened up as rural migrants flock to Bangkok for work and opportunity. The motorcycle taxi profession provides such opportunity for young uneducated males; it is one of the few relatively well-paying jobs open to these marginalized migrants (Obs. 73). As one interviewed architect/urbanist put it: “*Bangkok has to be a city for everybody. We are not just building a city for ourselves as native Bangkokians, we have to think, re-think and realize that this is city is for the whole country. Street vendors and motorcycle taxi drivers are mostly from the countryside and it has to be a city of opportunity for them as well. The Bangkok Metropolitan Authority knows all about this informal activity, but they have to turn a blind eye sometimes. Bangkok has to align two worlds together: the formal world and the informal world. Locally these worlds blend everywhere and they can’t exist without one another*” (Int. 16).

Another set of landscape trends, also reflected in interviewee claims, includes the shift in Thailand’s political- and economic landscape in the wake of the devastating shock provided by the 1997 Asian crisis. After the devaluation of the Thai Baht, the country became much more integrated in the global economy: as Thai Banks went bust the role of domestic capital declined and foreign capital poured in (Phongpaichit and Baker, 2008). Accompanied with foreign capital came little transfer of technological capabilities and more influence of transnational flows of expertise and knowledge in order to innovate in the context of Thailand's changing national innovation system (Intarakumnerd et al., 2002; Intarakumnerd 2006, 2011). Other institutional economists have also argued that Thailand doesn't have "*the educated workforce to exploit the potential for science and technology … [Thailand] has failed to develop this crucial social capacity and hence the technical competence of its people is very weak*" (Siripraichai 2012, p.44). In the wake of the Asian crisis Thailand's political landscape give way to a more populist turn in government policy from 2001 on. Below we will show how the remarkable rise of former president Thaksin Shinawatra and his policies to register drivers and bring the motorcycle win under centralized control have deeply influenced the way the motorcycle taxi regime is organized (Obs. 73).

Bangkok's motorcycle taxi regime emerged casually from humble beginnings. As people needed to move up and down the relatively long distance between residential area and the main street, extended families and community members casually picked up one another by motorcycle (constant regular taxi use would have been too expensive). The first dedicated motorcycle taxi services popped up in the early 1980's in the *Sathorn* disctrict on a side-road called *Soi Ngam Dupli*. The deep end of this long alley featured a high-density residential area and some low-ranking naval officers in this community developed a service group of motorcycle drivers solely for the purpose of shuttling residents up and down the alley. Other neighborhoods in Bangkok followed suit in the districts of *Don Muang* and *Bang Kapi*. Initially the metropolitan division of the Department of Land Transport registered motorcycles under the 1979 Motor Vehicle Act and not as a form of public transport, so they were technically illegal (also see Cervero, 2000).

Especially from the 1990's on, the motorcycle taxi phenomenon grew rapidly and a regime of territorial organization emerged as service groups were established in more and more parts of Bangkok. The Thai word for such a service group bound to a fixed location ('queue' or 'rank' in English), emerged in quick succession. The term '*win*' has been in use as early as 1982 and it is still in use today (Poapongsakorn, 1994, in Oshima et al., 2006). Despite the fact that the number of drivers and the number of *win* locations have grown explosively - there are now around 6000 of these nodes in the Bangkok's motorcycle taxi network - the key organizing principle based of each individual *win* remains the same: a group of motorcycle taxis are tied to a fixed spot (usually a street corner) and wait in a queue to take fair turns in servicing passengers who appear at the spot. Instead of 'roaming' around the city looking for other customers, the motorcyclists immediately return to their fixed spot after dropping off the passenger and wait in line for the next passenger.

The head of the territorial group, the *win-boss* (usually the one who initially claimed the spot and established the service group) manages the queue and can appoint new drivers. The turn-based system ensures a fair deal (and for some prime locations a relatively decent middle class income) for each driver as long as the number of drivers operating at given time at a service spot is managed prudently. Infractions are dealt with internally and the drivers need to pay the *win-boss* for their location specific orange vest (prices vary according to the passenger throughput and can be very high for lucrative spots) and for the privilege of operating.

In return for servicing a stretch of territory a bribe (a form of informal site rent) needs to be paid in order to keep the law at bay. So, establishing a win at a spot will tie both the win-boss and the drivers to a territory, to a 'protector' and to a succession of other local powerful people (police, ex-army officers, up to higher placed officials or politicians). These powerful people reap this system's informal benefits as drivers are shaken down and money and privilege trickle up the ladder (Obs. 64). Jurisdiction between different levels of government and their various agencies is unclear and in Bangkok's institutional environment of bureaucratic inertia the drivers do not have any firm legal standing. Initially, none attempted (or dared) to clean up the sector in order to limit the excesses of this kind of informality (also see Cervero and Golub, 2007).

In recent years, however, a number of efforts to formalize the informal organization of the sector have been undertaken. The most notable and politically high profile act towards formalization for the sector came from the Thaksin government in 2003. Under the veil of a 'war on dark influences' and in a stroke of populist brilliance Thaksin (then prime-minister, now controversial ex-prime minister) and Samak (then Bangkok governor) set their sights on the city's informal motorcycle taxi sector. They cracked down on the dark influences represented by those local powerful people (*soi mafias*), who were extorting motorcycle taxi drivers for informal site rent. As part of this effort, Bangkok's municipal government fitted the drivers with personally registered orange vests. Because of this act, and the subsequent passing of a by the house of representatives in 2004, the organization of the sector and its legal standing changed and Thailand became the first country in the world to legalize such a large motorcycle taxi force. As one interviewed transportation expert put it: "*What really surprises me is how Thaksin did that. There would have been so many parties, so many people – stakeholders if you will – who lost control*" (Int. 37). The legacy of these measures is that the regime is now slightly differently arranged (New Mandala, 2010) and that it 'looks' more formal. However, the old regime of extortion and informal rent proved to be deeply rooted and much of it remained in place or returned (especially after Thaksin was ousted in the 2006 military coup). Despite lax enforcement, these recent developments have empowered motorcycle taxi drivers and can be contrasted to Bangkok's situation several years ago, when drivers were not formally organized and when governments never formally intervened.

In the last few years, a similar move to re-organize came from within the motorcycle taxi regime. A group of politically involved drivers established a novel form of organization: the Thai Association of Motorcycle Taxi Drivers (AMTD). Membership of this union-like organization is on a voluntary basis and about 2% of Bangkok's motorcycle taxi drivers are members of this politicized group (though they can mobilize a larger numbers of riders). They wear their distinctive orange vests, embroidered with green lining and a large patch featuring two Thai flags and a Harley Davidson, with pride (Obs. 73). This organization seeks social justice and political bargaining power in their battle against the extortion of motorcycle taxi drivers. As part of their effort, the association mobilizes its members and other drivers and arranges rallies to put pressure on police chiefs or politicians. They seem to be exploring their new role in order to find a balance between two identities: on the one hand a union sticking up for the drivers and seeking legitimacy for the trade, on the other hand a politicized motor club. As the politically active association leader put it: "a*bout 90 percent of all motorcycle taxi drivers in Bangkok are being intimidated and forced into paying protection money. When a queue leader* ('win boss') *refuses, they will just take him out"* (Sunpituksaree, 2012). And "*We miss Thaksin, 100 percent. We can only wait for the new government to order the police to stop backing up mafia, then we can live*" (Bottollier-Depois, 2011).

In recent years, a number of alternative ways to re-organize the motorcycle taxi regime have been envisioned and enacted in the form of niche experiments. In many ways, these sociotechnical experiments are geared towards gnawing away the very core of a transport mode's informality. In 2010, a government test trial was started to set up registered stations - covered bus-stop-like metal structures - at truly fixed spots. The idea was conceived as a way to prevent certain stretches of road and sidewalk to be claimed illegally and to boost the motorcycle taxi image and to facilitate trust between driver and passenger (Obs. 21; Obs. 32). Also in 2010-2011, Bangkok's municipal government, in collaboration with an EV manufacturer and academic institutes in Japan, explored the possibilities for a test trial with electric motorbikes. The experiment would include only a small number of win and is set to start shortly (Obs. 21). Finally, in November 2011, an experiment was implemented to introduce a digitized ICT-platform to be used as a taxi-meter during a public trial. The following section discusses this experiment in more detail.

4.3. Metering motorbike mobility: in-depth analysis of a niche experiment

In a situation where fares are 'informally standardized' or negotiated on the spot through haggling, this ICT gadget enters the scene as a new brand and the first-ever taximeter for motorcycle taxis. The inventor of the device argued: "*It is almost inconceivable that an industry approaching 1% of the entire global GDP was still in search of a brand. Rarely in history has such a giant vacuum existed*" (Guerilla Stock Trading, 2012).

To uninformed observers, designing and implementing such a seemingly mundane device sounds simple, boring and uncontroversial. In reality, the development of a robust and tamper-free portable taximeter proved tricky and the very idea of calculating a fee differently is incompatible with many current practices. In case of the large-scale diffusion of metered mobility, this technology may be part of a major disruptive force in the entire motorcycle taxi regime or, conversely, this mismatch between present-day modus operandi and the alternative prescribed by a meter could also result in the failed diffusion of metering informal transport.

The device is potentially much more than just a meter; it is a ‘platform’. Like many other products, it can be revealed as serving multiple - and surprising - purposes. It could potentially be used as a black box, as a tracking device and as a smart card scanner to integrate payment with other transport modes. Some of these features represent a form a digitized control or surveillance and point to gloomy technological futures characterized as an Orwellian ‘digital panopticon’ (Urry, 2008). On the other hand, a typical taxi-meter feature like charging the passenger for waiting time encourages safe driving and the mere fact of having a meter on a motorbike conveys the message of a ‘bonafide’ operator, which could be instrumental in legitimizing the motorcycle taxi profession. Indirectly, if motorcycle taxi drivers perceive this as a way to empower themselves and their profession, it could possibly even help to undermine the reproduction of certain informal institutions such as paying informal site-rent and the associated chain of privileges and corruption.

A broad set of expectations surround the device. The entrepreneurs, who designed the device, mobilize discourses on environmental sustainability and position the experiment in this informal paratransit regime strategically against a regime of individual private transport dominated by the private car: *“Climate change is going to have serious consequences and most people have not considered how deeply our infrastructure is going to be affected as we move forward. We are going to have more environmental problems and look the amount of waste that goes on in the systems currently employed in wealthy industrialized countries. The current economic crisis is an opportunity to change a lot of the habits we’ve gotten into… Most people want to own five ton steel cars which are considered safe and they have wrong mindset to solve problems. Look at other [allegedly sustainable transport] options, like electric private cars: that may be good for a few people, but that’s not going to scale, it’s not going to make it to the masses. The ideal solution is never going to come, at least not for the majority of the world’s people. Let’s take a step back and realize just how useful motorcycle taxis are in solving a lot of issues. It’s neither beautiful nor sexy and it doesn’t have the appeal of an electric Tesla Roadster, but motorcycles are here today and they’re a workable solution”* (Int. 14). They argue that the emergence of a meter will increase safety, fairness and social justice within the industry: *“I really believe that the product we’ve got - a meter and more - is a technology that can contribute meaningfully to sustainability in the longer term”* (Int. 38). *“I’ve seen it in the eyes and tone of voice of the guys I've spoken with. It's just a feeling of, 'I've been marginalized for such a long time. Here's a device I can feel proud of myself with’”* (Fast Company, 2011).

The entrepreneurs expect large markets for their device all over the world, not just in developing cities, but as an integral part of a more fully developed motorcycle taxi industry all over the world (Obs. 81) serving as a crucial cog in many a city’s transit system: *“Motorcycle taxis are already large in numbers, but it’s going to grow. In the next 10-15 years I expect the motorcycle taxi industry to come into its own, also in the West. Look at cities in the US: the way they’re built is very spread out and it’s very difficult to put a mass transit system in. Where a bus line would initially not have worked,* *motorcycle taxis can act as the perfect feeders for that – they're cheap, small and they can operate anywhere – so they can expand viable transit coverage in many areas which had no public transport solution before."* (Int. 14).

Along a similar vein, online tech blogs fascinated with novelty and markets for new technologies stated that "*…the motorcycle taxis that dart through the streets of Thailand will be getting a new feature for the first time in history: a meter*" (Wired, 2011) and portrayed the device as "*one of the most significant innovations of this decade*" (Times, 2011) that "*… might just be a $3 billion dollar idea*" (Fast Company, 2011) which could be adopted throughout the world "*…there is huge potential to replicate this technology in all cities with motorcycle taxis*" (The City Fix, 2011), not just in developing cities, but all over the world it could spread from developing world cities to first world cities: "*the traditional thought process is that Western companies look to the developing world to find virgin markets for maximum growth; however in this case it's actually Europe that is filling the role of an emerging market.*" (Marketwire 2013). Diffusion may even not be limited to motorcycle taxis, but also to other vehicles and transport modes: *"they thought they had made a meter for motorcycle taxis. Really, they made a meter for anyone looking for a fare*" (MIT Technology Review, 2011).

These expectations and their visibility in the media were 'performative' (Van Lente, 2012) in the sense that they had an impact on the willingness of stakeholders in the trial to participate. Ever since this kind of media exposure, all kinds of stakeholders (fleet managers, drivers, governments) from different corners of the world approached the developers of the device to express their interest (Int. 38; Obs. 81). Even though the device was initially designed with the drivers in mind, the way in which its use develops will depend on the interests of other stakeholders as well (e.g. governments, passengers, fleet mangers seeking a higher degree of control). Since the organization of the motorcycle taxi regime and the institutional setting in which it operates are very different in cities throughout the world, the device can serve different interests: a fleet manager may want to keep track or exercise control over his motorcycle stock; a government may view it as boost for passenger safety or to aid regulating the sector; (acclaimed representatives of) drivers may view it as a way to gain legitimacy in the face of a governmental ban of informal transport.

In their attempts to implement the experiment, the entrepreneurs who developed the device sought to test their innovation not just on one motorcycle, but with an entire motorcycle taxi *win* against the backdrop of the complex socialities that make up day-to-day motorcycle taxi operation on the streets of Bangkok. They initially identified two main strategies. First, *bottom-up* (or what the entrepreneurs refer to as 'seeding the market' or 'injecting a virus into the system'). To test the device this way they could 'buy out a queue' – try to assume control over one win-location and its drivers. People would see the meters, other drivers would talk about it, word of mouth would travel fast and a number of devices would be in circulation before other key stakeholders would know what hit them. Second, *top-down* (or what the entrepreneurs refer to as 'going to government'). This would mean approaching key government stakeholders and to wait and see how cooperative they are to facilitate testing the device in real-life conditions. If government officials were to agree it could mean that they may lose some control over the details of hosting a trial. However, a potential advantage would be that cooperation with a variety of government stakeholders be beneficial at certain stages of the trial. The experience of dealing with these important authorities may be crucial for the future, since price setting and taxicab meters are usually regulated and governments may also play a key role in the future by possibly making meters mandatory for motorcycle taxis. Furthermore, if competing taximeter companies would appear on the scene at a later stage, the experience of having dealt with key government stakeholders and 'having done the dance' should give them an edge (knowing one another was thought to be important, especially in a developing city context where the rule of law is not always paramount).

For these reasons, they opted for the top-down approach and to attempt to get a trial going as a collective endeavor by aiming to include government stakeholders from the beginning. While contemplating whether or not to go to government with their device, the entrepreneurs talked to many people who were experienced in dealing with Bangkok's local government. These people (mostly expats) thought that getting government approval and implementing the device seemed potentially disruptive, controversial and a bureaucratic impossibility. They were proven wrong about the bureaucratic impossibility when the entrepreneurs went to government and in late 2010, a public meeting was hosted where different elements of Bangkok's legendary bureaucracy were all brought together: representatives of the governor, ministry of transport, treasury, district chiefs of police, etc. They all pledged their support for the trial (Obs. 80). One of the entrepreneurs mentions: *"Off course you never know what's really going on in the inside, but at least those people in power didn't look at it is a threat. The point is that they saw the value in the idea and recognized that there was something to it"* (Int. 38).

Different stakeholders attributed this 'value' in very different ways. Police chiefs wanted to test it in their district and speculated on what would happen when a device like this would be made mandatory. The metropolitan division of the Land Transport Department (a national-level authority), in opposition to the current governing body within Bangkok Metropolitan Administration (a city-level authority), was interested in becoming the designated entity to set the fare rate in case a motorcycle taxi meter would ever be mandatory in the future.

A crucial step towards the public meeting was a talk with the deputy governor of Bangkok. Her thoughts on the matter - "*an exciting project that will be an innovative step for Bangkok*" (Obs. 81) - point to yet another set of expectations concerning the 'value' of the device. With her backing things started to move quickly and hosting a government backed trial became one step closer. The idea of the meter as a gadget embodying technological innovation (and the fact that the deputy governor had backed the idea for that reason) was important in the eventual choice for the location where the trial took place. Initially some government stakeholders thought it would be a good idea to host a very big public trial at the crucial transit hub of *Victory Monument* with 200 devices and politicians and press on spot in full force at the opening of the trial. The entrepreneurs only had 30 prototype devices and they were not keen on such a big high profile test. Some politicians may seek political gain in opposing the meter and if the devices did not work properly or if something went wrong then a visible high profile test trial could hurt the future of their product. They would rather do a small low profile trial to see how drivers and passenger would respond and what kind of unexpected issues may pop up. Eventually a *win* was chosen at a relatively high-profile spot in the trendy *Thong Lo* area – this location was seen as fitting for a gadget embodying technological innovation and, on a more symbolic note, it is part of the district of *Watthana*, which translates as 'development'.

The actual experiment took place during the last few months of 2011 with 30 devices (Obs. 82). Over the course of the trial itself, the entrepreneurs gained more control to negotiate the spot for testing. The first tests took place in a large win with 150 drivers and not nearly as many devices. To avoid running into the potential danger that some drivers may feel excluded, they looked for another site in the same area and eventually a highly suitable win was found for the remainder of the trial. This win was near the Watthana district office, so that it would be easy for some of government officials working at this office to come and see the device in action. They also identified the micro-dynamics within the win conducting the trial as a crucial success factor. After all, the drivers would automatically serve as ambassadors for their product and they expected that a tightly knit group, small enough to supply every member with a meter, would mean less internal conflict. They found these requirements in a group of family members and extended family from the same village.

The entrepreneurs framed their lessons and acclaimed successes of their experimental efforts as a major victory and they framed the city of Bangkok as the important actor in the metered-motorcycle-story as the place where it all started: "*The successful completion of these trials is a particularly important milestone in the development of [our company] and marks the beginning of the era of metered motorcycle transport … Once [our device] is in widespread use, Bangkok will be referenced as a flagship city as the sales and marketing efforts are ramped up to enter other cities and areas across Thailand in conjunction with other major markets around the world.*" (Business Press 24, 2012).Important lessons were learned about the (sometimes surprising) roles played by a number of actors roles over the course of the trial. Passengers, by default, trust a digitized meter, even if they did not know how the fare is calculated exactly (Obs. 82). For the most part they played a rather passive role and just paid up at the end without asking any questions. Most passengers were regular users of motorcycle taxis, but none questioned the legitimacy of the meter or that it was fair in calculating the designated fee. The entrepreneurs and drivers had calibrated the fee in such a way so that the calculated fee would be more or less similar to the 'informally standardized' previous amount, but the passengers did not know this. Even when passengers had to pay a little more than usual they did not complain and hardly seemed to notice. It appears that passengers' familiarity with the 'user scripts' (Akrich, 1992) of metering devices in air-conditioned taxicabs would account for the seemingly blind trust put in a meter.

The drivers had some initial concern about using the device; what if this reduced their fee for a trip?

Would they have to compensate the device if it would be stolen from the bike? When they were assured that they would not have to pay up in case of theft and that they would be compensated for potential lower fees, they were willing to participate. Shortly after some devices were taken out of service briefly for maintenance/updates during the trial, the entrepreneurs started receiving phone calls from drivers asking when they could get their device back and they would have liked to keep it after the trial was over. Motorcycle taxi drivers, who were not implicated in the trial, also showed their interest for the device when they had briefly saw it on a bike at a traffic light stop or when they would visit the designated win to take look at the device for themselves.

The association of motorcycle taxis (AMTD) was not directly involved in the public trial, but played an interesting role nonetheless. The decision not to approach the association from the beginning was deliberate – it may have spelled trouble in dealing with some of the bureaucrats, government officials and police chiefs (*tessakhet*) who were involved in the public meeting (most of whom do not view the association as a legitimate stakeholder to deal with - Obs. 67). However, one week in the trial, the entrepreneurs decided to send a charismatic Thai friend and colleague to the association headquarters armed with three things: a device (to demonstrate how the taximeter worked), an iPad (to show a movie clip of trial) and a bouquet of red roses (Obs. 81). The color red was not a coincidence since the entrepreneurs viewed the association as linked to ex-prime minister Thaksin and the Red Shirt movement. The leader of the association received the envoy. The association had long since heard of the device being tested; not only through word of mouth, but it had also featured as a topic in their radio channel broadcasts. The association implicitly backed the trial and as a token, they handed the entrepreneurs their association flag (Obs. 81).

5. Conclusions

This paper aims to contribute to the burgeoning field of transition studies by extending current ideas and perspectives on transitions and mobility experiments to the unchartered territory of informal transport. We followed the career of Bangkok's motorcycle taxi industry from its emergence until recent efforts of experimentation with new technology and asked the question which implications can be drawn for the study of mobility transitions more generally. The following conclusions can now be drawn.

First, informal transport regimes are omnipresent and highly significant. To point this out we contrasted informal mobility in major developing cities with the predominant modes of mobility in Western contexts, i.e. an individual transport regime based on the car and a public transport regime to suggest fundamental differences exist. These informal systems are already vast in scope and size and they continue to increase in most developing cities - often more rapidly than their formal counterparts. In the case study, we argue for the significance of motorcycle taxies in Bangkok: an evolving system experienced by millions of travelers every day and of crucial importance in the wider context of the city's transport ecosystem.

Second, novel practices and dedicated efforts to innovate are taking shape in these evolving paratransit systems and in the informal institutional settings in which they operate. Our case study has demonstrated how different actors are implicated as agents of change in their recent efforts to formalize the motor-cycle taxi regime in Bangkok through political-, organizational *and* technological interventions. Our analysis revealed some of the intricacies of innovation and experimentation in this very different institutional context compared to Western settings, such as the lack of sufficient capabilities and resources to effectively deal with massive growth in demand; the importance of providing livelihoods to poor and marginalized people in the context of (sustainable) development; and the informal, mafia-like hierarchies stabilizing day-to-day practice in informal economies. We have only scratched the surface by showing how these novel practices are taking shape in the context for one tangible system and one specific experiment and it is far too early to generalize our findings. Further in-depth research should point out how efforts to innovate are taking shape in other kinds of informal transport systems against the backdrop of different institutional settings.

Third, ongoing efforts to innovate in informal transport systems potentially represent alternative development pathway (Berkhout et al, 2011) for mobility not yet recognized in full by transition scholars. Efforts to build on and optimize existing informal paratransit systems constitute an alternative track to modernize urban transport compared to more conventional mainstreamed efforts to upgrade the private car or conventional public transport systems (e.g. electrifying the car or innovative urban planning approaches to facilitate conventional MRT, BRT or light rail as part of a Transit Oriented Development paradigm). Moreover, if stakeholders supporting the innovation efforts in the motorcycle taxi meter project are to be believed, the impact and ‘spatial reach’ of their formalization efforts may even reconfigure places and mobility regimes beyond the borders of Bangkok and Thailand. ‘Formalized informal transport systems’ may turn out to become enduring parts of reconfigurations in mobility around the globe, e.g. as feeders or otherwise in novel combinations with new mass transit systems. An interesting next step would be to investigate how knowledge transfer from the Global South to the West could be facilitated and to find out what first world cities in the West - transport ecosystems devoid of paratransit except for the licensed taxicab here and there - could learn from cities in the diverse range of informal paratransit modes in developing world cities in order to incorporate some of the perks of these highly responsive, self-organizing, flexible and robust systems. Paratransit systems posses certain properties, which are also present in the envisioned sustainable systems that transition scholars argued for.

Fourth, ‘place’ and a variety of other socio-spatial dynamics are key factors for mobility experiments informal institutional setting developing cities. The analysis of the case study in this paper provides empirical insights for recent debates within the transitions studies community with regards to the role of cities and the ‘where’ of transitions (Hodson and Marvin, 2009, 2010; Bulkely et al., 2010) and the general need for a more geography informed perspective (Lawhon and Murphy, 2012; Coenen and Truffer, 2012; Coenen et al., 2012; Truffer and Coenen, 2012; Markard et al., 2012). We have showed how, at the scale of the street and the at the scale of the city, various socio-spatial dynamics matter, including the eventual site for testing as meaningful ‘place’, that is the location and what it represents to a variety of stakeholders, is a negotiated property and a contested matter.

Fifth, transnational linkages and other types of interaction between ‘the local’ and ‘the global’ were crucial to facilitate informal transport experiments. Experiments in developing contexts are located within transnational flows of knowledge, technology and other resources, which influence local capability development and, in response to the call of Berkhout et al., (2011, p.380), we aim to find out more about the underlying mechanisms. In each of the tentatively mentioned examples of ongoing informal transport experiments in section 3 of this paper, an international non-state organization is the initiating actor behind the experiment (e.g. the Asian Development Bank in the example for Manila; the European Commission in the example for New Delhi and a Harvard educated entrepreneur in the example for Jakarta; a start-up company by Canadian-American expats in the example for Bangkok). The analysis of the experiment in section 4.2 of this paper shows how a highly heterogeneous coalition of actors are involved in the experiment (e.g. foreign technology suppliers, city governments, marginalized operators), but also how media exposure (both local newspapers and tech blogs with a more global reach) can raise the stakes in and experiment and become a crucial starting point in linking innovators with possible market parties around the globe.

Sixth, by drawing on recent geography informed insights from both ‘the spatial turn’ in transition studies (Raven et al., 2012; Coenen et al., 2012; Truffer and Coenen, 2012; Lawhon and Murphy, 2012; Monstadt, 2009) and ‘the mobility turn’ in the social sciences (Sheller and Urry, 2006a; Urry, 2007; Cresswell, 2006, 2010) we may conclude that this sociotechnical experiment can be viewed as key site at which a multitude of ‘mobilities’ at multiple scales converge: the physical movement of motorcycle taxis through the streets of Bangkok, symbolically significant gifts changing hands, the drivers’ migratory paths between primate capital city of Bangkok and their rural birth grounds; the emergence of a meter, marvelously mobile, a piece of portable power able to jump not only from motorcycle to motorcycle but possibly to other transport modes as well, turning every vehicle into a potential taxi; the establishment of a transnational startup company by expat entrepreneurs and their communication with motorcycle taxi industry stakeholders throughout the world, who had learned about the development of motorcycle taxi meter through online tech blogs by surfing the internet’s electronic highway.

Finally, it should be noted that claims about the sustainability and possible futures for informal paratransit systems are inherently political and rife with conflicting considerations. On the one hand they contribute to congestion, air- and noise pollution, traffic accidents and sometimes they undermine the viability of other (more environmentally sustainable) public transport systems. Their rise is part and parcel of the ongoing process massive unrestrained motorization, which is taking its toll on the livability of many a city. On the other hand, there is more to the concept of sustainability then only an environmental component: mobility is a basic human right. In some cities they are the only public transit options available, which provide access for the urban masses and job opportunities for the poor. In many cities they patch together a broader collection of public transport systems and contribute to the package of multi-modality geared to undermine the relentless rise of the private motorcar. Regardless of the issues and the difficulties to rationalize them from a public policy perspective, the mobility needs and the livelihoods of millions of urbanites depend on these informal transport systems. Far from a decline suggested by some development economists, informal paratransit systems are thriving and in many cities their growth outpaces that of their formal counterparts. As transport scholar Geetam Tiwari (2005, p.1) put it: *"the actors in this complex street environment cannot be wished away … they are here to stay"*. This makes informal transport systems a key area for future research in the context of mobility transitions.

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A Grassroots Sustainable Energy Niche? Reflections on community energy case studies

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1 Introduction

The combined pressure of global climate change, threats to energy security and peak oil are driving a research agenda toward developing a radically more sustainable energy system (UKERC, 2009; Grin et al, 2010). The UK government's Low Carbon Transition Plan presents a national strategy for climate and energy which includes reducing energy consumption through conservation and efficiency measures, and the development of low-carbon electricity generation systems (HM Government, 2009). A key element of this plan is the role of households and communities, and the government's aim to "create an environment where the innovation and ideas of communities [in response to climate change] can flourish" (ibid p.92).

Community energy projects are one example of this type of grassroots-led innovation, which aim to create more sustainable energy systems. They encompass a wide range of initiatives such as locally-owned renewable energy generation, community hall refurbishments, collective behaviour change programmes, and so on, and are claimed to bring additional public engagement benefits to top-down policy initiatives. Community energy has therefore been proposed as a new policy tool to help achieve the transition to a low-carbon energy system, but little is known about the scope and potential of such community-led innovations to influence wider transitions in the energy system.

To understand the dynamics of system transformation, we turn to theories of socio-technical change which have examined the role of protected 'niche' spaces as seedbeds of radical innovation. Niches are claimed to develop from clusters of sustainability innovations (projects), and in turn help new projects get established, and therefore diffuse the innovation more widely, potentially becoming robust enough to compete with – and influence or displace – existing, less sustainable systems (Geels 2005; Kemp et al, 1998; Raven et al, 2008). Strategic Niche Management (SNM) is a governance approach to nurturing these niches as seedbeds of sustainable innovations, and sets out the conditions and processes for niches to become robust and influential (Schot et al. 1994, Kemp et al. 1998; Hoogma et al, 2001). While research within this field to date has focused on managed technological innovation in market contexts, a growing body of work on 'grassroots innovations' is examining bottom-up civil society-led initiatives for sustainability (Seyfang and Smith 2007). This work aims to better understand values-driven, community-based initiatives for sustainability, in order to support their growth and achieve wider influence. To this end, we examine the extent to which SNM can be applied to this novel innovation context, in order to gain insight into how grassroots innovations in sustainable energy might be harnessed to support policy goals.

We present new empirical evidence from a study of the community energy sector (comprising many local projects) in the UK, and investigate the extent to which a community energy niche is evident. We draw on three main bodies of data: a set of 12 in-depth qualitative case studies of community energy projects; a review of resources available from networks and intermediary organisations representing the sector; and 15 in-depth interviews with key actors working at this level. We ask: to what extent is a community energy niche emerging, and at what stage of development is it? to answer this, we study how community energy projects might be contributing to niche development, and how effective networking and intermediary organisations are at helping new projects to get established and keep going.

The paper proceeds as follows: section 2 reviews the theoretical context of this work, identifying the areas of research which are currently undertheorised, and introduces the empirical case we study here, the UK community energy sector; section 3 describes our methodology; section 4 presents our findings, which we discuss in section 5. We conclude in section 6 with insights for policy and practice from the application of this niche analysis to support the sector's development, and identify further avenues of research.

2 Theoretical context

Innovative niches for sustainability transitions

Theories of innovation for sustainability have adopted co-evolutionary models of social and technological systems to understand the drivers and dynamics of system-wide transitions (Geels, 2005; Grin et al, 2010). Sociotechnical systems (eg water, energy, transport, food) are theorised as 'regimes' existing in a state of dynamic equilibrium. They are resilient and therefore display technological lock-in and path-dependency, resulting in only incremental improvements in sustainability performance. Innovations for radical system-change must therefore come from without the regime, and historical reviews of systemic transitions have identified innovative niches as an important source of radical innovation (e.g. Schot and Geels, 2008). This work has been developed into a normative approach to governing innovation for sustainability: Strategic Niche Management (SNM).

Niches are conceived as protected spaces where novel sociotechnical configurations are established (often as a direct response to an unsustainable regime), experimented with, and developed, away from the normal selection pressures of the regime. They are conceived as 'cosmopolitan' (ie not situated) spaces, constituted of multiple on-the-ground local projects, linked together by networks and intermediary organisations (Geels and Deuten, 2006; Hoogma et al, 2001; Raven et al, 2008). These intermediaries at the cosmopolitan or niche level consolidate the learning flowing 'up' from projects, and repackage it into mobile forms as transferrable standards, best practice and other resources to help new projects, who in turn re-interpret and embed the knowledge in new local contexts. In this way they aggregate learning and resources to help grow the niche through replication of projects, and influence regimes to adopt niche ideas and practices. Tensions in regimes, such as energy security issues, cast niche solutions in a positive light, thereby attracting interest from policy-makers and businesses in the regime.

Niche development is therefore seen as a necessary (but not sufficient) condition for the wider diffusion of innovative ideas and practices. Geels and Deuten (2006) theorise this process as a linear trajectory of a 'cosmopolitan' (ie abstracted, mobile) niche emerging over time from a group of local projects. Figure 1 illustrates this model, moving from a set of isolated projects (*local* phase), through an *inter-local* phase where projects share knowledge and experiences on an ad-hoc basis and a niche level begins to emerge; followed by a *trans-local* phase where local knowledge is systematically fed 'up' to constitute the aggregated learning required at niche level, to a final *global* phase where the niche coordinates and frames local projects and becomes robust enough to influence or displace the regime (Figure 1).

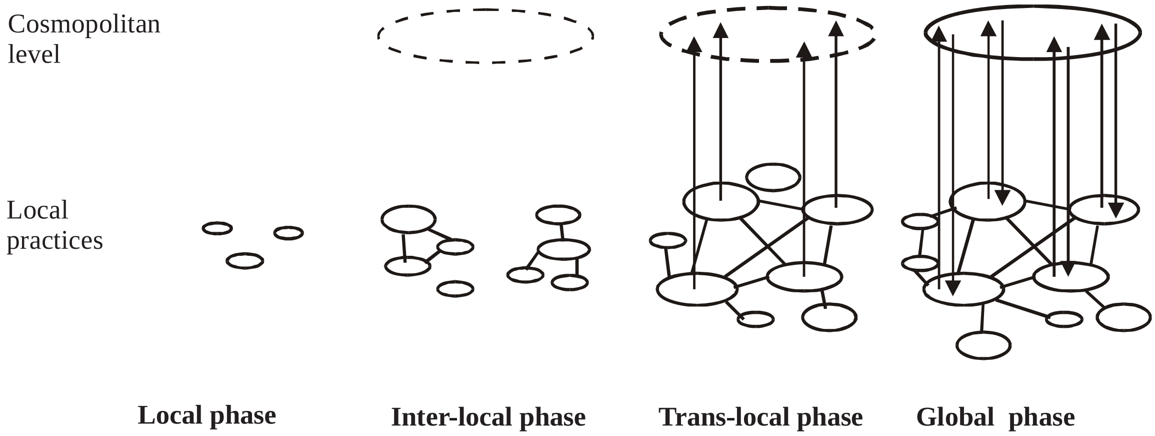

Figure 1. Phases in the development of shared technological knowledge (Geels and Deuten, 2006: 269)

Niche analyses of systemic change have studied the conditions under which niches become influential, with the potential to diffuse their innovations into wider society, and have identified three areas of activity which constitute effective niche-building: expectations, networks and learning. These suggest that: **expectations** about innovation performance contribute to successful niche building when they are robust (shared by many actors), specific, and of high quality (substantiated by ongoing projects); **social networks** contribute when their membership is broad (encompassing plural perspectives) and deep (representing substantial resource commitments by members); and **learning** processes not only accumulate facts, data and first-order lessons about how to improve the innovation, but also generate second-order learning about alternative cognitive frames and different ways of valuing and supporting the niche (Kemp et al, 1998; Hoogma *et al*, 2001). Niche practices become influential to the extent that these three processes become robust enough to influence wider institutional changes (Geels, 2002; Raven, 2006).

Whilst useful, this basic model has problems. One, which our research counters, is essentialising simplifications of niche-to-regime analysis. The niche-to-regime model simplifies a complex plurality of socio-technical configurations (i.e. community-led initiatives) into unrealistically homogenous niches working against a similarly problematic homogenous regime (Shove and Walker, 2007; Genus and Coles, 2008). This points to a second difficulty, which is the under-theorised relations between located socio-technical projects and the emergence of an abstracted, niche-level identity and interest, based around stylised, transferrable and abstracted socio-technical practices: what makes 'sequences of projects gel into a niche' requires further examination' (Schot and Geels, 2008: 544) (see also Raven *et al*, 2008; Smith, 2007; Seyfang, 2009). This is problematic in terms of explaining niche development: how do community projects reinterpret, reinvent yet reinforce the generic, mobile lessons and norms constituting a niche? Theory is vague as to the precise roles of projects in niche-building, and the specific manner in which niches influence, coordinate and frame local projects, contributing to wider diffusion.

In analysing the potential of an innovation to influence wider systems, therefore, we need to assess the extent to which these processes are occurring, and which phase of niche development the sector appears to be exhibiting. Our empirical analysis will therefore examine the nature of interactions between projects and intermediary actors, to assess whether and to what extent a niche can be identified.

Grassroots innovations

Most niche analyses to date have focused on market contexts and business-led technological innovations. In contrast, a growing body of work studying grassroots innovations frames radical community-based action for sustainability as an overlooked site of innovation for sustainability, and seeks to better understand how they might be harnesed and supported to diffuse. Grassroots innovations are defined as:

> "networks of activists and organisations generating novel bottom–up solutions for sustainable development; solutions that respond to the local situation and the interests and values of the communities involved. In contrast to mainstream business greening, grassroots initiatives operate in civil society arenas and involve committed activists experimenting with social innovations as well as using greener technologies."
>
> (Seyfang and Smith, 2007:585)

Grassroots innovations differ from market-based innovations in several key ways: their driving force is social and/or environmental need, rather than rent seeking; their context is civil society rather than the market economy; they display diverse organisational forms including cooperatives, voluntary organisations and community initiatives, rather than firms; their resource base is voluntary input, grant funding, mutual exchange, and reciprocal relations rather than business loans and commercial income; they are grounded in local and collective values, based on notions of solidarity, rather than efficiency and profit-seeking; and their niche protection consists of being a space for alternative – i.e. green, sustainability-oriented - values to be expressed, as opposed to shielding from market forces (Seyfang and Smith 2007).

Recent studies have examined grassroots innovations in the context of complementary currencies (Seyfang and Longhurst, 2013a,b), energy (Seyfang and Haxeltine, 2012; Hielscher et al, 2013; Hargreaves et al, 2013; Geels and Verhees 2011; Ornetzeder and Rohracher, 2013; Hess, 2013), food (Smith 2006; Seyfang, 2009; White and Stirling, 2013; Kirwan et al, 2013) and eco-housing (Avelino and Kunze 2009; Seyfang 2009; Smith 2006). While individual initiatives and sectors invariably differ from each other, a common finding across all these studies of grassroots innovations which relate to their distinct characteristics, is the set of internal and external challenges they face in simply surviving, let alone growing, replicating and spreading more widely. Often initiatives fail to grow because of an absence of long-term resources and institutional support. In addition, the radical values which led to the niche formation can clash with commercial and policy priorities, making the translation of innovative practices challenging, even with dedicated intermediaries. The importance of robust analysis of these initiatives is clear, then, to enable policymakers to harness the innovative energies of community groups working for sustainability.

In turning to SNM to understand grassroots innovations, we reframe community-led initiatives for sustainability as innovative niches, and so gain insight into how these might be supported to overcome the challenges they face, and diffuse more widely. A SNM analysis should identify the interventions, resources, policies and interactions required to develop a robust niche with greater potential for influence. But it is unclear how appliccable the lessons of SNM are in this civil society context where the nature of the innovations differ so markedly to those market-based niches more normally considered in the literature, and most importantly, where the niche has emerged through a bottom-up process rather than through strategic management. In order to assess the utility of SNM in this new setting, therefore, an empirical exploration of an emerging grassroots innovations sector is required.

Community Energy: a grassroots innovation niche?

The last few years have seen a flourishing of community-led sustainable energy projects (hereafter 'community energy') in the UK, building on an historical foundation of alternative energy initiatives from the 1970s, and benefiting from recent policy measures to support the transition to a low-carbon economy. The term 'community energy' is applied to a wide range of initiatives with varying degrees of community involvement; here, we follow Walker and Devine-Wright's (2008) lead and consider community energy to refer to those projects where communities (of place or interest) exhibit a high degree of ownership and control, as well as benefiting collectively from the outcomes.

These grassroots innovations include both energy generation and conservation projects such as: village hall refurbishments introducing high levels of insulation and energy efficiency, combined with micro-generation technologies; collective behaviour change programmes such as Carbon Rationing Action Groups, Transition Streets or Student Switch-Off; community-owned wind turbines like those on the Scottish Isles of Eigg or Gigha; cooperatively-run small-scale energy systems, for example, Ouse Valley Energy Services Company (OVESCO) or Brighton Energy Cooperative. They are typically instigated or run by a diverse range of civil society groups, including voluntary organisations, cooperatives, informal associations etc, and partnerships with social enterprises, schools, businesses, faith groups, local government or utility companies (Clark and Chadwick, 2011; Adams, 2008; Seyfang et al, 2013).

Policy support for community energy in recent years has arisen due to the sector's ability to engage local populations in sustainable energy issues, improving public receptivity to renewable energy installations, increasing engagement in behaviour-change initiatives and reducing carbon emissions as a result. Thus, communities are seen as critical players in sustainable energy generation and energy saving efforts: "Community energy is a perfect expression of the transformative power of the Big Society" (DECC, 2010). To this end, several policy initiatives have explicitly aimed to catalyse increased community energy activity, and DECC's Low Carbon Communities Challenge (DECC, 2009) aimed to learn from a series of exemplar projects: what potential they have to contribute to a low-carbon energy transition, and how best to seed wider change at the community level. However, the question of how local projects grow and spread, becoming transferable and generalisable, has not been addressed until now.

This existence of dedicated networks, support groups, policy strategy, a growing number of local projects and recent academic interest suggests that a community energy niche may be emerging. If this is the case, then SNM may be able to inform future developments and provide insight into the most important future developments for long-term influence. We therefore look for evidence of a community energy niche being formed from the activities of local projects, and for intermediary actors helping to support and replicate projects on the ground; we assess which stage of niche development (Figure 1) is displayed by the sector, and what is required to further develop the putative niche. By analysing the community energy sector using a niche innovation framework, we can begin to understand the processes by which potential diffusion and harnessing for policy objectives might be aided.

3 Methodology

The findings presented here are drawn from mixed-methods qualitative research into the UK community energy sector, focusing on both project- and intermediary-level activities. First, we conducted twelve in-depth case studies of community energy projects (see Table 1), sampled principally for diversity of activity (of both supply and demand-side interventions) and pioneer (ie pre-2007)/follow-on replicated projects (in our survey of UK community energy projects, 21% were pioneers, established before 2007; Seyfang et al, 2013). Each of these studies comprises site visits and in-depth face-to-face interviews with 3-6 elite informants (e.g. founders and key partners), supplemented by document analysis of self-published material such as project websites. We investigated the objectives, activities, origins and developmental trajectory of the groups, and analysed the cases according to theoretically-informed themes around project-niche relations, learning, networking and expectations. These case studies were published as 'innovation histories' (Hielscher et al, 2012), charting the evolution of each group's project and highlighting niche-building-relevant activities along the way (see www.grassrootsinnovations.org for the set of innovation histories). These have been subsequently coded and analysed below according to the theoretically-informed criteria we have derived, and using the coding criteria shown in the tables below. In addition, the nature of learning and flows of resources between projects has been recorded, and is categorised according to the following capitals model:

- **Natural capital**: e.g. a site for a wind turbine or a hydro scheme, or wood-fuel/biomass for burning.
- **Manufactured capital:** e.g. a building in which to have meetings or on which to place solar panels, or particular equipment or tools e.g. cranes, diggers, carbon calculators etc.
- **Human/Organisational capital**: e.g. skills or training, labour (whether voluntary or paid), knowledge and information, opportunities for trialling/piloting and building experience.
- **Social capital:** e.g. personal contacts, credibility, licenses (which are usually granted on the basis of a level of 'trust'), publicity.
- **Financial capital**: e.g. funding whether as a grant, loan etc.
- **Cultural capital:** e.g. inspiration, moral support, a catalyst to action, a counter-cultural community, alternative values in the area.

From these innovation histories, we developed an innovative qualitative social network analysis methodology to examine the nature and substance of significant network links from each project, coding each network tie for partner (local or national? energy-related or not? public, private or third sector?) and the substance of what flowed (coded as various types of capital: manufactured, natural, social, human/organisational, financial, cultural).

The second strand of research investigated the activities and resources of actors and organisations operating on behalf of local projects (the potential niche-level) which might have the potential to frame and coordinate future projects. This consists of 15 in-depth semi-structured elite interviews with representatives of intermediary organisations including national and regional NGOs, government bodies, and private sector companies. These variously act to initiate, network, support, fund, lobby for, promote and coordinate the community energy sector in the UK (see Table 2). These were also sampled for geographical spread throughout UK, to cover the areas of community renewables, energy efficiency and behaviour change, and to capture the full range of possible intermediary roles. In addition, we examined the resources made available by intermediary organisations to spread knowledge and inspiration about community energy. We collected 113 reports produced by intermediary organisations (ie – produced by a third party, not self-produced) about specific local community energy projects, and conducted a content analysis to assess the types of knowledge and information being conveyed (see Hargreaves, 2011; Hargreaves et al, 2013).

Table 1: The twelve community energy cases studied

Name	Description	Energy Domain	Country	Started	Current status
Barley Bridge Weir Hydro Scheme	Cumbrian project to use a local weir for community owned hydro-electricity generation.	Supply and demand	England	2007	On hold
Brighton Energy Coop	Aims to run and finance renewable energy projects in Brighton and Hove. Recently established a cooperatively owned 145kWp solar PV project funded by public share issue	Supply and demand	England	2010	Growing
Bristol Green Doors	A community interest company that promotes energy efficiency through retrofit measures on existing home. Organises open eco-homes events in Bristol.	Demand	England	2009	Growing
Carbon Conversations	Runs community-based programmes of facilitated meetings in which participants discuss the practical and emotional challenges of low-carbon living and design strategies to reduce their carbon footprints.	Demand	England	2005	Growing
Glasgow Carbon Rationing Action Group	Members calcuate their annual carbon emissions and self-impose rationing; reductions through efficiency improvements and behaviour change; penalties for not reaching reduction targets; support and advice in group context.	Demand	Scotland	2006	Continuing
Dyfi Solar Club	Sought to make solar water heating technology cheaper and more accessible to residents of the Dyfi valley and later across Powys more widely. Member of the National Network of Solar Clubs	Supply	Wales	1999	Finished
Hyde Farm Climate Action Network	Raises awareness about energy consumption in the home. Draught-proofing measures, installation of loft insulation and renewable energy generation to improve the energy efficiency of local housing stock.	Demand	England	2007	Growing
Isle of Gigha Heritage Trust	Completed a community buy-out of their island in 2002 and as part of the regeneration programme installed three wind turbines and conducted various energy efficiency projects.	Supply and demand	Scotland	2006	Growing
Lyndhurst Community Centre	The first community centre in the New Forest to install a biomass heating system, creating opportunities for local wood fuel supply networks to develop.	Supply and demand	England	2001	Continuing
Reepham Green Team	An informal social network that aims to develop and deliver a wide range of projects to tackle issues of concern to the local community, eg school refurbishment and renewable energy generation	Supply and demand	England	2002	Growing
South Wheatley Environmental Trust	Generating energy from their 15kW wind turbine, selling it to the grid and investing the surplus in local household energy efficiency projects, renewable energy projects and energy education at local schools.	Supply and demand	England	2003	Continuing
Student Switch Off	Behaviour change campaign that uses prizes and competition between student halls of residence to encourage students to undertake small energy-saving actions.	Demand	UK-wide	2005	Growing

Table 2: brief description of intermediary organisations sampled for interview – specify intermediary role as well as geography, type of activity covered

	Description of group's relevant activities and role as an intermediary							
Name of Organisation	Initiating	Networking	Supporting	Funding	Interfacing	Energy Domain	Area covered	Type
Energy Saving Trust		X	X			Supply and demand	UK	UK-wide NGO
Centre for Sustainable Energy		X	X	X	X	Supply and demand	UK	UK-wide NGO
Global Action Plan		X				Demand	UK	UK-wide NGO
Low Carbon Communities Network		X			X	Supply and demand	UK	UK-wide NGO
Transition Network		X			X	Supply and demand	UK	UK-wide NGO
Community Energy Scotland		X	X	X	X	Supply and demand	Scotland	Regional NGO
Community Renewable Energy		X				Supply	North-West England	Regional NGO
Development Trusts Association Scotland		X				Supply and demand	Scotland	Regional NGO
Marches Energy Agency	X					Supply and demand	Midlands	Regional NGO
DECC		X		X		Supply and demand	UK	Government department
Scottish Government		X	X			Supply and demand	Scotland	Regional Government
South East England Development Association		X				Supply and demand	Regional within England	Government organisation (disbanded)
Good Energy		X				Supply	UK	Private sector utility company
Independent consultant		X	X		X	Supply and demand	UK	Private sector consultant

Note: intermediary groups have the following roles:

- **Initiating** new projects
- Sharing information and developing forms of **networking** between community energy groups
- Providing tools (e.g. carbon calculators) and resources (e.g. good practice case studies and handbooks) to **support** projects
- Managing and evaluating **funding** programmes
- **Interfacing** with policymakers and energy companies to further develop community energy

4 Findings: Is the UK Community Energy Sector an emerging niche?

We aim to assess the evidence for the development of a community energy niche in the UK, as evidenced by project contributions to wider shared knowledge and learning, networking and shared visions (section 4.1), and conversely, by intermediary oprganisations' influence and support in framing and coordinating new projects (section 4.2). To the extent that one is fund, we evaluate the phase of development it appears to be displaying. Given that our twelve cases were sampled for diversity, it is reasonable to presume that any activities or findings which occur across all or almost all the cases, may be generalisable to community energy as a sector in general, and may additionally raise pertinent questions for further investigation in other domains of grassroots innovations.

4.1 'Upward' flows: are projects contributing to developing a niche?

4.1.1 Learning

Sharing learning is an important activity for our cases (the criteria for our coding is shown in Table 3), as predicted by the SNM model of niche development, which shows that the types of learning, and the people with whom it is shared, varies over time and according to different phases of the development of the sector.

All our cases showed evidence of learning being shared 'upwards' with intermediary organisations operating to network and share experiences between local groups (thereby contributing to knowledge aggregation and consolidation), to some extent. Four of the groups did so to a 'high' degree (for example, developing replicable financial models); three did this to a medium degree (e.g. working with intermediary organisation to develop mentoring programmes) and five only to a low degree (such as when a project ends and learning is not formally consolidated)(see Figure 2). Interestingly, the intermediary organisations this learning was shared with were not necessarily or exclusively *sustainable energy* actors (see Figure 3). Although the majority (10) did share their learning with energy intermediaries (such as Centre for Sustainable Energy, Energyshare, Energy Saving Trust) and almost as many (9) with wider sustainability-focussed organisations (such as the Low Carbon Communities Network, and COIN), in fact all the groups shared knowledge with other organisations beyond these, such as Highlands and Islands Enterprise, Development Trusts Association Scotland, community energy consultants, farmers, researchers, businesses and local government. Some of the learning has therefotre contributed not necessarily to developing a community energy niche, but rather to suppporting renewable energy or community development instead – a subtle but important distinction.

Table 3: Coding criteria for sharing learning

Sharing Learning	High	Medium	Low
with intermediaries	Groups are actively engaged in articulating their lessons learnt and experiences with intermediaries and circulating them between projects (sometimes becoming an intermediary themselves).	Groups engaged in circulating their lesson learnt and experiences with other groups that share the same approach (such as Transition Towns) and associated intermediaries (such as Transition network).	Groups interact with and potentially share their learning with intermediaries that are not directly connected to the community energy sector (such as Ben & Jerry's). In some cases the learnt lessons flow not directly into the sector or even get lost along the way.
with other community groups	developed infrastructure for sharing learnt lessons that could be accessed by other community energy groups such as mentoring programmes and project walking tours.	These groups also developed infrastructures for sharing learning (such as websites and booklets) but mainly for their own locality or approach rather than the whole community energy sector.	Groups did not actively articulate or circulate their learning.
within the project	Groups exhibit active learning through direct experiences when developing and realising the project – such as learning by doing, experimenting and learning through dealing with failure.	Groups rely on the skills and knowledge members initially brought to the project, including past experiences that they gained working within community energy.	Groups had few applicable skills when starting the project and found it difficult to learn from their perceived failures.

The most prominent mechanisms for sharing learning were being written about by intermediary organisations as exemplars in case study reports (10), filling in application forms for funding programmes (10) and actively engaging with intermediaries to develop transferable knowledge (9). These are all passive activities, which indicates that for most of the groups, sharing is something that others do *to* them, rather than groups doing it for themselves. Only half of the projects were actively engaged in formal evaluation or monitoring processes whereby learning was consolidated and passed to intermediaries, and therefore key lessons have frequently been lost at the end of projects. Occasional exceptions exist where community energy intermediaries work more closely with the initiatives, for example, Bristol Green Doors gained financial and advisory support to set up an Ecohome mentoring programme to aid the replication of their approach. We found human/organisational aspects of projects were the most commonly shared (by 11 groups). The next most prominent was cultural capital (shared by 9 groups), and 3 groups shared social capital from their projects. Very few groups shared either financial or manufactured capital aspects of the work, and natural resources were not shared at all (see Figure 3). The evidence suggests therefore that 'upward' flows of lessons and learning are not particularly strong, and quite a lot of the shared learning is going to intermediaries outside the community energy niche.

In contrast, sharing of learning directly with other community groups was much more evident, and was engaged with to a greater extent (see Figure 1). The majority of groups (7) did this to a high degree; 2 medium and 3 low. The profile of organisations they shared knowledge with were different at this level: 11 shared learning with other community energy groups (eg similarly-focused local organisations, or other groups within their 'family' of projects), while two thirds (8) did so with wider sustainability-oriented community groups (such as local Transition Towns groups, Climate Action groups, etc) and 5 with 'other' types of community groups (for instance Rotary Clubs, Women's Institute, church groups, ethnic minority groups, etc).

The principal mechanisms of learning-sharing at this level were quite distinct to those in the 'upward' flow of sharing with intermediaries. At this level, they were mainly through peer-to-peer information sharing (meaning informal, ad hoc contact by telephone, email or at events, to acquire information and advice) which they ALL did , developing replicable models (9), and through hosting visits to their projects (7). Fewer were involved in mentoring other projects directly (5) and being a local test-bed for innovation (6), although this is a promising diffusion route: for example when local community energy initiatives came together to test a project idea (sustainable travel) in one of the villages to learn from it and then spread it more widely across the villages. Some of the groups developed local newsletters and shared websites to provide infrastructural support for project-to-project information sharing with similar interest groups. The substance of this learning shared project-to-project was human/organisational (ALL) such as carbon footprinting resources and advice; and cultural (ALL) e.g. conferences for group facilitators within a project 'family' to share learning but also offer moral support, and social (4) e.g. having overlapping memberships between groups to develop a critical mass of activists in the area (see Figure 4).

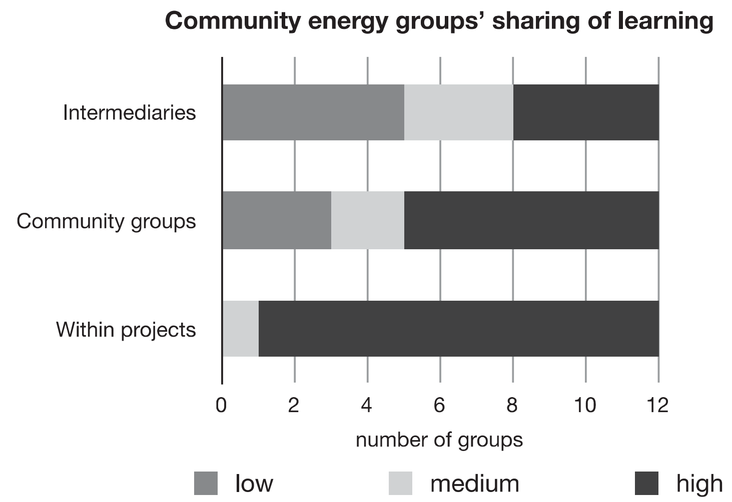

Figure 2: The extent of community energy groups' sharing of learning

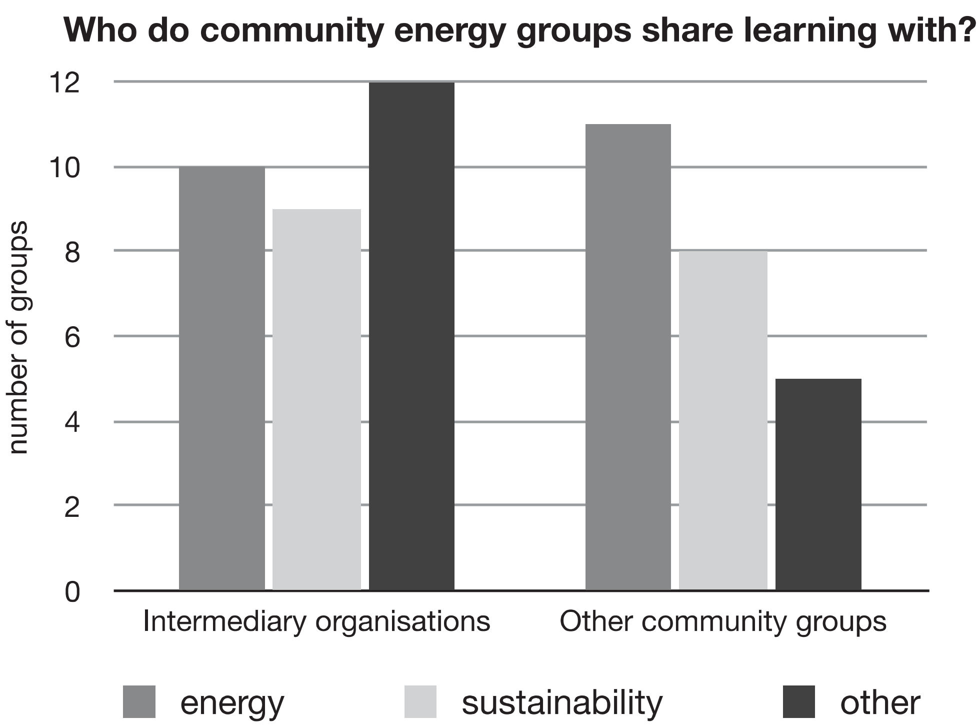

Figure 3: Who do community energy groups share learning with?

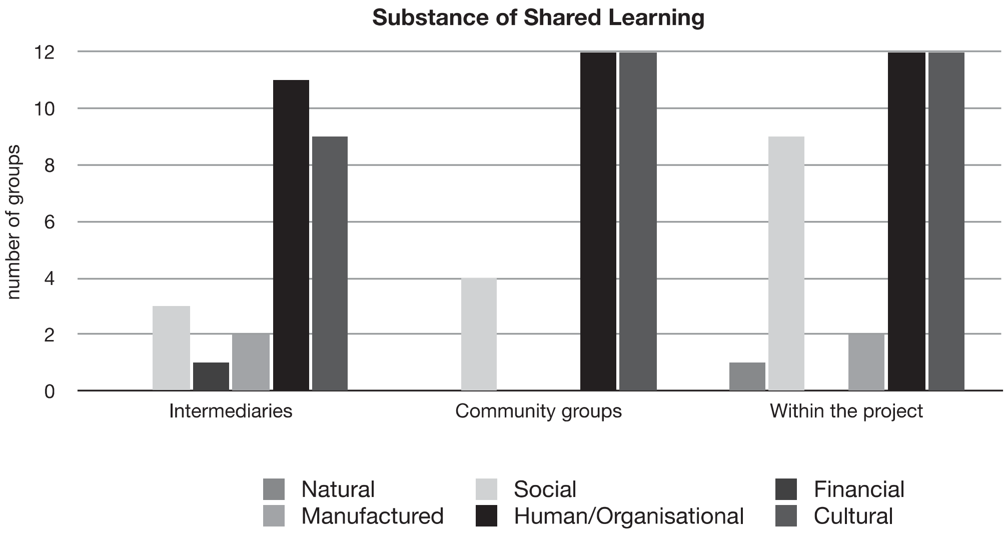

Figure 4 The substance of what is shared by community energy groups at different levels

In addition to these *outward-facing* processes of sharing learning with other groups and organisations, we found that learning plays an important role *within* groups in developing, improving and evolving community energy initiatives. The vast majority of our cases (11) engaged in this to a high degree. The most prevalent means through which this occurred was 'learning by doing', which was found in all the cases, and took the form of, for instance, adapting their activities to better suit local contexts and conditions and improve community engagement and effectiveness. All cases also drew on pre-existing expertise within the group, such as project management, form-filling, ideas for community engagement, etc. Reading around the subject and internet searches for information were significant sources of learning for 10 projects, and public meetings also generated project-level learning for 10 groups. The types of learning were principally human/organisational aspects such as developing the initiative's model and rationale (all 12 cases), cultural aspects (all 12) and social (9). This is because while some initiatives were extremely effective in attracting members that have professional skills required to develop their projects (such as accountancy, project management and engineering), *all* the projects needed to learn and acquire additional skills and resources to successfully embed their project into the local context. This was often based on building emotional stamina and creating soft skills in order to deal with setbacks and lengthy project development phases.

To summarise this section, the evidence indicates that some learning is being shared upwards with community energy intermediaries, although mainly by passive means rather than through formal evaluations, monitoring and structured, codified learning mechanisms. Furthermore, the niche being contributed to is not necessariy energy-focused but may represent wider sustainability, regeneration or community development interests. In contrast, projects are much more engaged with sharing learning directly with other community groups through informal, ad hoc channels – although again, these are not necessarily energy-focused. When we compare the extent of activity taking place at each level (see Figure 2), it is clear that sharing learning with more community energy intermediary organisations takes second place to sharing learning with other community groups; furthermore, sharing learning within the projects themselves is very significant to the projects' development and progress. In all of these cases, the content of the learning being shared is overwhelmingly around human/organisational and cultural, as well as social aspects of running community energy projects. These are likely to be indicative of the grassroots innovations nature of the sector, reflecting the fact they they tend to be reliant on these types of resources, rather than financial, manufactured or natural capital.

4.1.2 Networking

Community energy projects engage in networking activities in a variety of ways, with a diverse set of partners, to gain support, information, and share their experiences (see Table 4 for our coding criteria for networking activities at various levels). Projects can contribute to building cosmopolitan-level networks in a variety of ways, for instance through participating in network-level events, boosting memberships of intermediary organisations, applying and embedding intermediary-produced resources and tools, thereby increasing the sector's reach, and so on. There is good evidence that all our cases are engaged in *actively* contributing 'upwards' to network-building at this level (see Figure 5). Some also have more passive, reactive or chance networking links with these partners, and a few have pre-existing network links to actors this level. The main mechanisms by which this happens are: filling in online templates for funding applications or for intermediaries gathering data on the sector (11), media and publicity work in responding to public interest in their projects, or proactively seeking publicity to help develop their projects (11). Around two-thirds of the cases also attended intermediary-run events such as the Low Carbon Communities Network conference, etc, were a member of a wider network, talked to policy makers or lobbied directly, or worked with external consultants to produce materials and resources for the intermediary organisations. These activities helped to raise the profile of community energy and encouraged interactions between initiatives, but were sporadic and irregular. The main resources (capital flows) which are exchanged with actors at the global level are human/organisational capital (ALL), cultural capital (ALL) and social capital (4).

Table 4: Coding criteria for Networking

Building Networks	Pro-actively	Reactively	Pre-existing
with intermediaries	Groups actively mentor other CE initiatives as part of programmes set up by intermediaries, work with external consultants to produce learning materials for the community energy sector or talk about their project at network events.	Attending CE events, filling in applications forms, becoming a member of a network.	Groups rely on existing relationships with intermediary organisations that they already had before starting the project.
with other community groups	Groups set up their own mentoring programmes, host other community energy initiative for a day or plan networking events.	Groups do not intentionally or strategically try to build relations with particular individuals or organisations but rather connections occur accidentally.	Groups rely on existing community energy relations that they already had before starting the project.
within the project	Groups conduct public meetings, talk with local decision makers and organisations and visit other community energy initiatives.	Groups do not intentionally or strategically try to build relations with particular individuals or organisations but rather connections occur accidentally.	Groups rely on existing local, friendship and contacts that they already had before starting the project.

In addition to these contributions 'upwards' to network-building with intermediary organisations representing the sector, most of the groups were also pro-actively networking with other community groups (eg hosting visits from other community energy group members, or holding events to raise their profile) although at this level they were more reliant on pre-existing contacts (7) (See Figure 5). This mainly happened through being part of a 'sustainability family' , for example developing connections between projects that share an a particular model, and wanted to support each other and develop materials for wider diffusion – e.g. Transition Town groups, or Bristol Green Doors being part of a network of Eco-Open Home projects (9 groups) and hosting visits from other community energy groups to come and see their work in operation (8), and holding community energy events (5). Formalised local mentoring was rare.

As before, the main resources gained from this networking at community group level is around human/organisational factors (all 12), and cultural capital (11), with some social capital (4) resources flowing too (see Figure 5). In terms of having strong connections to other groups, our cases are principally connected to local sustainabiity 'families' (6 of the 12); others benefit from being located in a green milieu (ie a 'hotspot' for alternative green values and practices; for instance Brighton Energy Co-op's investment drive was helped by a populace sympathetic to their aims) (5), and only one is particularly rooted in a strong local culture dedicated to fostering regeneration.

Finally, we find that network-building within and around the community energy groups themselves is very important, in the development and operation of their activities. As Figure 4 shows, all projects were actively engaged in network-building at project level, and they all also drew on pre-existing contacts to bring new partners and resources into the project. The main ways this within-project networking took place were through talking to local decision-makers to gain political credibility and influence (all 12 projects did this), drawing on informal personal (ie friends and family) contacts for support and resources (11), and pre-existing professional network connections from different sectors, eg accountants, lawyers, membership lists of other green groups, etc (10), in both cases to bring in skills and expertise needed by the project. Holding public meetings (9) was another route to building project networks, identifying interested parties, local expertise and potential group members. This reveals the extent to which community energy projects rely on the skills-base, resources and prior contacts which members bring to the group, to get established and keep going. Again, human/organisational capital and cultural capital are the principal resources gained at the project level, but we see a much stronger flow of social capital into the projects at this level (8).

In summary, we find that networking is a vital aspect of the development of these community energy groups, and that while there is good evidence of contributions to global-level networking, as predicted by SNM in the formation phases of niche-development, there is more activity and reliance on pre-existing networks both between groups, and within individual groups, and with actors from other sectors/interest groups. This indicates that the sector is currently at the 'inter-local' phase of niche development, showing greater reliance on project-to-project connections than those with intermediary organisations. At each level, though, the principal resources flowing through these network connections are human/organisational and cultural in nature.

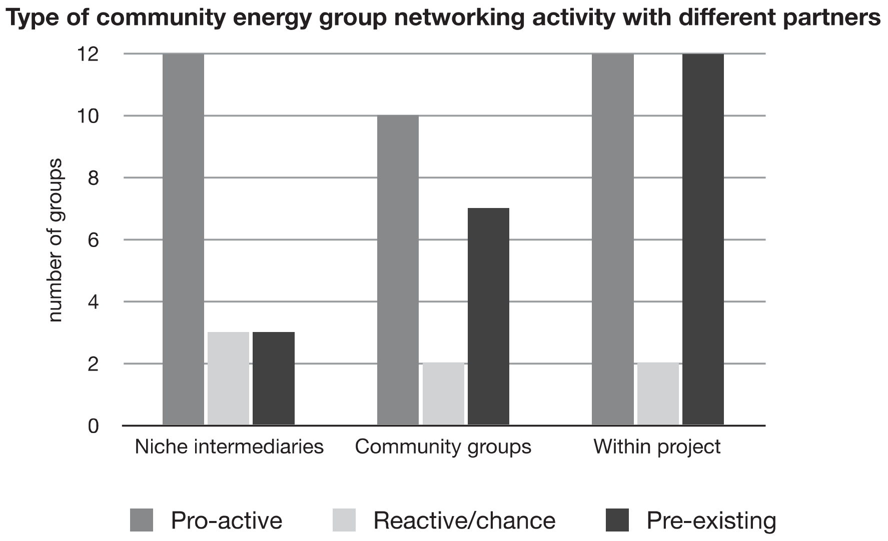

Figure 5 Community group networking activities with different partners

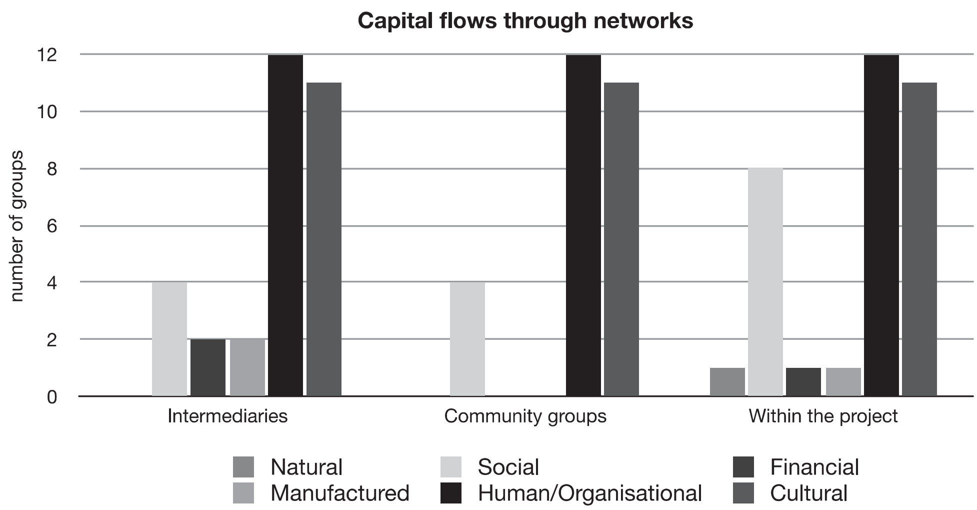

Figure 6 Capital flows through network links with with different partners

4.1.3 Expectations

The development of shared expectations and visions is considered a pre-requisite for robust niche development, and the role of local projects in this process is somewhat less direct that in the previous sections. We sought, therefore, evidence of coherence around visions and expectations between projects, as this would necessarily feed up to intermediary-level activities, interests (and indeed, the choice of which intermediaries to interact with).

The twelve cases had a diverse range of rationales and visions. All but one had sustainable energy objectives, while all twelve were motivated by wider sustainability goals, and seven also aimed to promote community development. These multiple and overlapping visions were expressed in various ways, for example Brighton Energy Co-op's mission statement covers several bases: "energy co-ops are powerful vehicles for engaging local communities on energy issues. Community-owned energy gives local people ownership of energy generation, makes those who receive the green energy less vulnerable to energy price increases, and empowers communities to improve their local environments" (Brighton Energy Cooperative, 2013). Given these typically broad-ranging aims, it is perhaps not surprising that the majority of groups (10) were aiming to achieve wider societal change beyond their own projects, which we can describe as being 'strategic' projects. These groups were aiming to achieve a systemic change in the energy system. Examples include Carbon Conversations who aimed to support widespread changes in daily practices and associated energy demand, and Brighton Energy Co-op who aimed to replicate their project and run several interlinked initiatives, growing in scale, market share and influence. Only one group was focused solely on achieving their own goals with no wider strategic aim, this was the Lyndhurst biomass project which wanted to refurbish their community centre and reduce their fuel bills, and we refer to this as a 'simple' project. One group began as a simple, locally-focused project, then evolved into something with wider objectives and became more involved in the sector as a whole.

We found that all the projects had very clear visions of their goals and objectives, and around half the groups have maintained their visions and over time (8) (meaning groups had formulated and articulated unchanging, well-defined project aims, benefits and future promises and only had to adapt their ways of achieving them) while the others have evolved and adapted their aims and objectives (including adapting their intended benefits and future promises, as well as evolving new ways of achieving them). For instance, the Barley Bridge Weir Hydro Scheme started off wanting to develop a community-owned energy generation project but after conducting a public meeting decide to widen their aims, setting up various linked sustainability projects in the village around food, transport and energy. For these projects, the flexibility and adaptability shown by shifting priorities and visions has enabled groups to develop more successfully and engage more deeply with local populations, thereby contributing to their success – even if this is redefined over time.

We explored to what extent did community energy intermediary actors influence or inspire the development of project visions and expectations (which would indicate propagation of a shared vision, and coordination of local projects demonstrative of an advanced phase of niche development), and were surprised to find that *none* of the projects were originally inspired or instigated by intermediary-level organisations. Rather, two-thirds of the groups got their initial idea directly from hearing about or seeing other community energy groups, and a third were inspired by other types of organisation such as the Highlands and Islands Enterprise, District Councils, individuals developing the Carbon Contraction and Convergence model, and so on. This indicates that there is not yet an influential niche able to shape the development of future projects within its overall shared vision, and that the sector currently exhibits characteristics of the 'interlocal' phase regarding shared visions and project coordination. As a result, the multiplicity of objectives and visions held by community energy groups contributes to a pluralistic sector, and one which has to date failed to unify around specific goals. This is not least because there is a strong distinction between groups pursuing energy generation objectives, and those solely focusing on energy conservation and demand-reduction. This distinction will become apparent in the following section.

4.2 'Downwards' flows: are intermediary actors contributing to project development?

The previous section has reviewed the evidence of community energy groups' activities around learning, networking and developing shared visions, in order to assess the extent of the projects' cpontributions to the development of a community energy niche. A key purpose of niche development, of course, is to enable wider innovation diffusion through the provision of consolidated learning, best practice, business models, technical expertise and so on. The model claims that these can be 'drawn down' to enable new projects to start up more easily. In this section we examine the evidence for intermediary-level organisations providing resources to support the development needs of local projects, to assess the extent to which projects are supported on the ground.

4.2.1 Skills and resources offered by community energy intermediaries

Actors working within the community energy sector include dedicated energy intermediaries, policy actors such as local and national government, and private sector organisations such as energy utilities and independent consultants. The national, regional and local dedicated intermediary NGOs providing resources to would-be and established community energy projects include Centre for Sustainable Energy, Energy Saving Trust, Carbon Leapfrog, Marches Energy Agency, Low Carbon Community Network, and they are generally grant-funded (Hargreaves et al, 2013).

The consolidated knowledge being aggregated at this global level is made available to new projects in various ways, most prominently in the form of documented reports about previous exemplar projects, and handbooks, toolkits and 'how-to' guides. In addition, these organisations may also initiate new projects themselves, offer advice and support, share information and establish network links between projects, provide tools such as carbon calculators, and access to professional services such as financial or legal advice. Direct mentoring schemes exist (eg Community Powerdown was a collaboration between two Scottish intermediaries and local initiatives to share learning and provide more organised mentoring support) but are resource- and time-intensive, and therefore rare.

The 'success story' reports represent the first wave of resources produced to help new projects, and are intended to provide a vital source of inspiration to local activists about what is possible, and encourage them to start new projects. These reports are usually quite short (2-3 pages long) and include key facts about a particular project: name, location, source of funding, start date, activities and results etc, and often the key lessons learned by the projects (see section 4.1.1 above). Our analysis of the learning conveyed in these reports indicates that a very wide range of lessons are identified, and that despite every best effort to learn from previous experience in the sector, each project faces some very context-specific challenges which will not necessarily be encountered by others or known about in advance.

Over time, these reports have come to be supplemented and even supplanted by more detailed handbooks and 'how-to' guides which provide more detail on the processes and challenges involved in developing local community energy initiatives. Where the exemplar reports focus on whole projects, these toolkits and handbooks concentrate instead on specific elements of local projects (e.g. around organisational structures; funding models; communications and consultation techniques etc.) and, as a result, identify and aggregate learning about common features found in many types of project. Importantly, these generic processes are often illustrated with specific and detailed case studies that serve to demonstrate how these more general principles and processes must also, and always, be employed in locally appropriate and sensitive ways. This seems to represent a move forwards from general inspiration-provision which might be most appropriate for a nascent sector, towards aggregating (and providing) more detailed learning on the concrete issues faced by new groups within a maturing field.

In terms of policy support available to projects, there have been various funding initiatives – prize competitions, grants etc – which have sought to develop exemplars and learn about how to spread and grow community energy, eg DECC's Low Carbon Communities Challenge. More recently, under the Conservative-Liberal Democrat coalition, a significant shift has occurred away from grants and the subsidy of upfront investment costs, and towards revenue guarantee schemes to encourage new forms of 'community enterprise'. The Feed-in-Tariff, for example, provides guaranteed, above market rate payment for each unit of electricity generated from approved and certified, small-scale renewable electricity technologies. What this means for community groups is that they now have to adopt more business-like models, whereby they generate investment capital from sources other than grants. Other recent examples within this general approach are the Green Deal for home energy efficiency measures, and the Renewable Heat Incentive. The community energy intermediary organisations have responded by updating their advice and resources, but it seems that they struggle to keep up with a shifting policy landscape and moving targets, and this lack of stability in the sector is felt most keenly by local projects who find their plans are undermined by policy changes.

4.2.2 Skills and resources needed by new projects

Community energy projects need a variety of resources to get set up and become established. In the twelve cases we studied, the main areas of resources, knowledge and skills needed were:

- social (all cases) e.g. building supportive links with experienced or inspirational activists and groups to provide credibility, resources and advice;
- human/organisational (all cases) e.g. conducting a community carbon audit as a first step towards identifying potential projects; developing project marketing skills;
- cultural (all cases) e.g. being embedded within a prevailing alternative culture or strong local regeneration movement provided a solid basis for community support;
- financial (11 cases) e.g. grant funding needed to carry out the project, to buy equipment, pay for key staff, or premesis, etc.

This was the only area where we found a distinct difference between those projects working on energy-generation, and those with only demand-side activities. Natural capital needs were exclusively identified by energy generation projects (3 out of 3, for example needing a piece of land to site a wind turbine, or finding suitable sunny locations for solar PV cells), and manufactured capital needs were primarily found in these projects too (4 out of 5) such as physical tools and equipment to carry out impact assessments and audits, feasibility tests etc.

This demonstrates that community energy projects require 'soft' or 'people' skills, which are often as important as technical skills in overcoming challenges, building determination and persistence, and growing their projects. Similarly, in addition to interpersonal skills, initiatives need personal and emotional support to keep the project going in the even most challenging times. Here, in particular, face-to-face networking activities between initiatives can help, and knowing that other initiatives go through similar challenges can provide confidence.

Acquiring the resources to meet these needs was a key activity for the groups and essential for their development. All the projects we studied were pro-active in gaining the skills, knowledge and resources they needed; most of them drew on pre-existing knowledge and resources from within their community group; and a few also benefited from passive or chance encounters to access the resources they required. The groups drew on a variety of sources to meet their needs, both within and beyond the community energy sector.

All the groups were able to self-generate some of the resources they needed (perhaps by recruiting participants with particular skills, or by conducting research and training themselves, etc), and they all accessed resources provided by intermediary organisations – but these were not necessarily energy-focussed groups: two thirds of the cases gained skills, knowledge and resources from energy-specific intermediaries (primarily these were the energy-generating groups), two thirds from wider sustainability organisations (primarily the demand-side only groups), and all but one drew on resources from *other* types of organisation including parish councils, planning departments, council sustainability teams, statutory bodies Natural England

and English Heritage, Universities, local farmers, freelance professionals, and energy utilities. In addition to these intermediary organisations, groups' needs were addressed through direct contact with other community energy groups (9), from national and local government support (9) and other sources (such as the church, solicitors, businesses, local organisations and farmers) (5).

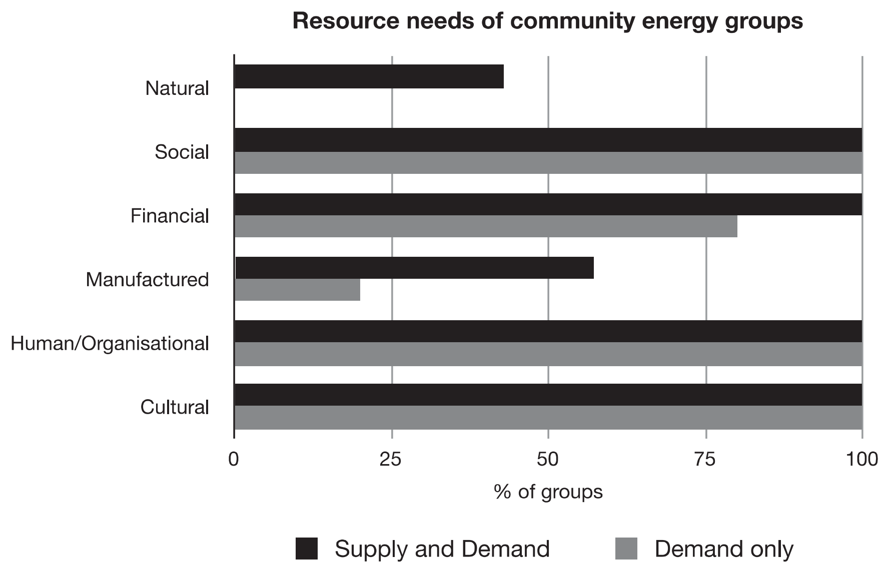

Figure 7: Resource needs of community energy projects

4.2.3 Where do local groups get support from?

It seems that to some extent, the needs of community energy groups are being recognised by dedicated community energy intermediary groups and other actors working to support the sector: financial support in the form of grant funding and community energy business models is available (though limited), and community energy organisations are disseminating lessons and inspiration to spread the ideas and inspire (and support) new projects. Technical advice, expertise, and inspiration is all on offer to help new projects become established. However, there are some critical needs which cannot be met through the provision of handbooks and toolkits, namely the need for social skills, confidence, emotional stamina to keep going even in challenging times, the ability to comprehend and apply unfamiliar and uncommon organisational structures, decision making processes and financial models, and a capacity for local context-adaptability and flexibility. Finally, a stable and benign policy context is a critical need for the development of the sector.

In addition, we see that community energy groups gain support and resources from a wide variety of sources in addition to dedicated community energy organisations – perhaps a mirror of the phenomenon seen in section 4.1 where they are engaged with wider sustainability and community development organisations and fields, at least as much as with energy-specific ones. So from the project's point of view, only some of their needs are met by specific community energy intermediaries and they must look beyond this, to access the skills, knowledge and resources they require. From the intermediaries' perspective, they too are struggling in an unstable policy context, and are equally under-resourced and over-stretched in their objectives to support the sector. These groups are continually learning and updating their knowledge about how to best support projects and manage these demands within constrained budgets and capacities. This indicates that at present, there is not a particularly good fit between the support offerings of the community energy intermediaries, and the resource needs of projects, suggesting that there is not yet an effective niche able to coordinate and frame new projects, and diffuse niche practices.

5 Discussion

Our analysis of the UK community energy sector reveals that there is indeed some evidence of an emerging niche of the type described in SNM (identified by dedicated intermediary and network organisations, and policy support, and contributed to by local projects). In terms of the phases of niche development set out by Geels and Deuten (2006; Figure 1), the sector shows some evidence of the 'trans-local' phase, but overall most strongly exhibits the characteristics of the earlier 'inter-local' phase, whereby project-to-project links are the most important and intermediary-level actors and organisations are only just emerging and beginning to play a role in terms of aggregating projects' learning and sharing resources with new projects. Despite its achievements, this sector is a nascent and far from robust niche, which theory suggests is not yet able to exert influence or diffuse more widely. Our SNM analytical approach indicates some possible routes for developing the sector in niche terms, to move from the 'inter-local' to the 'trans-local' phase, and a number of challenges to be overcome in so doing.

Principally, in order to become a more developed niche, this sector needs a stronger set of intermediary organisations with the capacity to consolidate and aggregate the learning and experiences of local projects, repackage them for implementation elsewhere, and lobby effectively for policy and industry support. At present, we see these intermediary organisations struggling with resource constraints and running to keep up with dynamic policy contexts in order to constantly update their understanding of what works, and continue to support projects on the ground. Simultaneously, a diverse and dynamically-evolving variety of local projects are springing up and experimenting with new technologies and approaches, adapting to local contexts and changing conditions, yet without systematically capturing or sharing their learning, and without consolidation of models and techniques. SNM suggests that better-resourced intermediary organisations could take the initiative in offering resources to new projects, transferring lessons from local projects, liaising with energy utilities and policymakers, and developing standardised models for easier replication. Financial support for these dedicated sector-development organisations and networks is critical to help the sector coalesce into an effective niche, as is the exogenous condition of a benign and stable policy context within which to develop support mechanisms, best practice, advice and standards. Additionally, effective boundary organisations such as Carbon Leapfrog play a vital role in 'translating' between local projects and policy/commercial actors who cannot relate to small scale voluntary organisations; this type of intermediating work is critically important and demands consistent and adequate support.

However, the distinct grassroots innovative characteristics of the community energy sector presents additional challenges and demands attenuation of these SNM-derived prescriptions for niche development. First and foremost, though there is evidence of an emerging niche forming, what we see in this civil society context of grassroots innovations is that it comes from the bottom-up, and is *neither strategic nor managed*. This has important consequences for the viability and resourcing of putative niche-level actors, and for the policy context in which they operate, as mentioned above. While community energy has successfully grown up in between the cracks of the mainstream energy system, it needs to be nurtured and supported (i.e. pro-actively supported, if not strategically managed) if it is to continue to grow and develop.

Second, in a related area, the nature of the *protection* which this proto-niche benefits from presents a challenge for niche-development. The kinds of protection we see in grassroots innovations tends to be around spaces where stronger sustainability values are expressed and practiced (as opposed to market protection through subsidies and regulation). While important for bringing together committed volunteers sharing certain values and ideals, this protection is less practically helpful in terms of developing viable and well-resourced projects. It is admirable and inspiring to see the amount of innovation and experimentation, commitment and dedication demonstrated by community energy activists, but this is not a sufficient basis for a viable future sustainable energy system. For the sector to mature and develop requires dedicated work to develop commercial models and easily adoptable systems that can work in a wider range of communities.

Third, the resources available within community energy projects (principally social, human and organisational capital, as opposed to, say, financial, natural or manufactured capital) and the support needs of new projects are distinctive to grassroots innovations; the resources offered by intermediary organisations to new projects needs to adapt to these and better meet their requirements, to enable more widespread diffusion. Practical resource needs are important, but equally so are more 'soft skills' and social competencies such as confidence-building and moral support, to establish new projects and keep them going. Intermediary organisations are not meeting these needs at present; groups have to look elsewhere for those resources and support. For dedicated community energy organisations and networks to support projects more solidly would demand a high level of resource-intensive support, such as face-to-face mentoring and training workshops, which have also been among the first things to be cut back in the current economic climate.

Fourth, as community energy is so heavily grounded in local civil society and community engagement, some of the necessary project learning required to get initiatives up and running is particularly context-specific. But it seems that community energy initiatives and intermediaries have yet to develop generic and transferrable principles that are widely applicable within the sector. Actors who want to support community energy might need to nurture infrastructures that aid the process of learning-by-doing and encourage interactions between 'do-ers' to allow this tacit knowledge to spread (as it may not travel so well in the form of abstracted toolkits), while consolidating generic principles thereof. Formal facilitated mentoring, for example, might be one way of achieving this, but again resourcing issues are a concern.

Finally, it has to be questioned whether this putative niche will ever coalesce into a single movement with influence: although SNM developed around the model of single novel technologies, here we see many different approaches, technologies and social innovations bundled together into a community energy sector – the potential for these to align in terms of visions and expectations, performance and interests, is unclear. In the meantime, we see projects sharing knowledge and experience with actors in a variety of sectors and fields, perhaps contributing to the development of sub-niches (the technology-specific sustainability families discussed above) or alternatively to broader sustainability niches around community development, regneneration and so on.

6 Conclusions

We have examined the UK community energy sector in order to establish to what extent it is displaying characteristic of a community energy niche – with the potential to diffuse and influence wider energy systems. We found that an emerging niche is evident, but it is at the 'inter-local' phase: neither strategic nor managed, and is rather incoherent in terms of its direction, content and substance. Projects tend to learn from each other rather than from dedicated networking organisations, and intermediary organisations struggle to meet the support needs of local projects. Despite the impressive growth of the sector in a context of inconsistent and constrained support, it is evident that the nascent niche we see is neither robust nor influential. Dedicated intermediary organisations struggle to influence policy decisions (a UK community energy strategy is currently being developed – watch this space) and shifting policy contexts undermine local efforts to build projects.

Applying principles of Strategic Niche Management (SNM) to this sector would suggest that there is a need for more positive policy spport and interventions to improve the resourcing of intermediary organisations who can do the important work of consolidatng and aggregating learning from local projects, thereby to better develop transferrable and generic lessons which can be diffused and implemented elsewhere. However, this sector has emerged spontaneously from civil society and sustainability-focused activists, and its grassroots innovation characteristics bring additional challenges. In this context, the predictions and recommendations of SNM are somewhat less helpful, as the presumption of benign policy context and governance interventions to support the emerging niche cannot be substantiated.

Therefore, we argue that grassroots innovations, while offering a promising yet neglected site of innovation for sustainabiity, require attention and support beyond the governance prescriptions of SNM. If community energy in the UK is to contribute to a shifting energy mix, it requires imaginative policy support, recognition of its distinctiveness as an innovative sector, and appropriate support and resources to enable a more robust niche to take shape. Perhaps, given these conditions, we may then see community energy become more influential in the UK energy system and help meet policy targets for sustainable energy.

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Draft version

DESIGNING FOR SUSTAINABILITY – MOBILITY SYSTEMS BASED ON ELECTRICAL VEHICLES

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ABSTRACT

In parallel with transition studies design scholars have discussed how design and designers could develop design practices capable of transcendence established unsustainable socio-technical practices. It concerns both how we may understand the agency of designers, structural conditions of design practices, and the very object of design.

This study departs from the understanding that 'designing for sustainability' demands reflexivity on the contextual framework of design practices: the technological regimes and design spaces, where 'design spaces' are the specific situated configurations of networks of actors, specific interpretations and discourses and structural conditions in terms of institutional and material interdependencies, all structuring design practices. The object of 'designing for sustainability' is socio-technical practices embedded in socio-technical systems and specific socio-political frameworks – and design includes interventions at a structural level of socio-technical systems and practices. The challenge of sustainable design, from this perspective, becomes a question of how to change socio-technical regimes, and 'designing for sustainability' becomes a project of meta-design, concerned with design as meta-level processes of regime transformation and the constructive configuration of design spaces.

The case study examines an attempt to integrate electric vehicles in the Danish mobility systems. It maps the framework conditions and contemporary (competing) strategies/projects, but focuses on a specific car-sharing project ('Cleardrive'), with the objective to examine the early and constitutive stages of the design-process. It is conducted as an intensive study tracing elements of interpretation, interaction and intervention, which have been part of the project formation process.

The 'Cleardrive project' is based on the understanding that the diffusion of electrical vehicles should be related to change in mobility behavior/practices and integration with the public transportation system. Main efforts of the design process have been to reframe the problem (a metadesign of design places in interaction with public authorities and transportation companies), configuring the electric car sharing system as an element in an alternative mobility service system, and designing the technical and organizational system

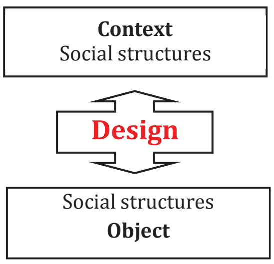
The concluding discussion falls into two parts: an assessment of the design process in the 'Cleardrive project' from a transition perspective, and a discussion of how we may integrate design and transition studies.

Key words: *Transition, sustainable design, design spaces, metadesign, mobility service system*

INTRODUCTION

The point of departure is an understanding of designing for sustainability as interventions in practices in specific socio-technical contexts. It makes transition of socio-technical systems and practices the focal point of sustainable design. In addition, designing is understood as embedded in regimes/design spaces making sustainable design a question of reflexivity and transcendence of dominant regimes. It is a dual perspective on design as practices contextually embedded in social structures (regimes/design places), and as intervention in social structures (socio-technical systems/social practices) (see fig. 1).

It calls for reflexive design practices challenging dominant regimes and shaping alternative design spaces and for design as interventions in socio-technical systems, including changes of the related values and socio-technical practices of users and communities – an analytic focus on design as a reflexive reconfiguration of design places and socio-technical systems.



Design: embedded interventions

Design (Design practices and methods) embedded in and constrained by social structures (economic, political, cognitive, technological)

Design as interventions in social structures and practices (intentional and transformative)

Figure 1: Design as embedded interventions: socio-technical systems both form the contextual conditions of and become the object of design (for sustainability)

The structural perspective of design as embedded in socio-technical regimes and the analysis of design practices takes reference to Giddens structuration theory and critical realism. Giddens (1984) argue that the rules and resources drawn upon in the production and reproduction of social action are at the same time means of system reproduction. Knowledgeable designers perceive the socio-technical regimes and select specific elements as important for the structuration of the design places. The critical realistic perspective emphasizes that there is a social reality but that there are different perceptions based on theoretical and normative preferences because the social reality are not fully transparent. The social systems are open systems and therefore outcomes are contingent (Sayer, 2000). This means that the designers understanding of the important factors in the socio-technical regimes are crucial for the definition of the design place and that the definitions can change during the design process.

The research study examines the transition to mobility based on Battery Electrical Vehicles (BEV). The specific case is the emergent design of an electric car sharing systems (cleardrive.dk, Copenhagen), following the early constitutive design stages of the project. It traces the processes of problem definition, interpretation and reframing, and the processes of co-development of design solutions and practices in specific contexts. On a general level it addresses how 'designers meet metadesign problems' at specific design places, which can be acted within. It examines design as a process, where designs evolve through cycles of learning based on acting within a specific field (design space) and where designers in a reflexive process by acting in the field may co-shape alternative design places.

PART I: ANALYTIC FRAMEWORK

DESIGNING FOR SUSTAINABILITY

Design for sustainability has evolved as a core design issue as a response to fundamental social challenges of climate change, resource depletion, and health and environmental problems. Designing is, following the understanding of Simon (1984), enacted distributed in society as intended effort of changing existing situations into preferred ones (*Everyone designs who devises courses of action aimed at changing existing situations into preferred ones,* (ibid:111)). Designing for sustainability calls for an intentional, normative design practice with the capacity to redefine products and practices, and capable of being reflexive and radical. Focus is not on the grounding in present practices and competences, but how to transcendence given structural constrains and facilitate structural changes and shifts in social practices. From the perspective of Simon, everyone acting within a field with the objective to change the field, become designers.

The challenge is the design of sustainable social practices (Stegall 2006), expanding the focus of sustainable design from artefacts and production systems to the inclusion of every day practices; we have '*moved from largely technical concerns about efficient resource consumption and minimizing waste in our existing industrial systems to a more recent focus on the very social issue of lifestyle change*' (Thorpe 2010:3). Sustainable design, perceived as the formation of more sustainable practices, combines structural changes and shift in practices (Shove/Walker 2010).

TRANSITION OF SOCIO-TECHNICAL SYSTEMS AND SOCIAL PRACTICES

Designing for sustainability goes beyond eco-design schemes of more sustainable products – it concerns the transformation/transition of socio-technical systems and of social practices. It implies that we depart from the understanding, that socio-technical systems both form the contextual conditions of and become the object of design (for sustainability); we need to understand how socio-technical systems and practices are constituted and further understand their dynamics of development, reproduction and change.

SOCIO-TECHNICAL SYSTEMS AND DESIGN

The notion of socio-technical systems has been introduced with the objective to understand how both social and material elements structure and constitute technology and social practices. It has a structural aspect, understanding how socio-technical systems consist of network of actors, institutions (rules), artefacts (holding meaning and power prefiguring agency) – we have aligned and co-developing elements of technology, production systems, service systems (e.g. maintenance systems), markets, consumer behaviour/user practices, policies (regulation, institutional framework), infrastructures and cultural meaning (Geels 2004). It is an actor-based approach asserting the importance of actors/stakeholders, the framing of their actions, their interpretation/perception, interest and strategies and their networks and interaction, as both constitutive and dynamic properties of socio-technical systems.

This socio-technical perspective on design imply that both an understanding of the structural relations of functional elements (technology, products, infrastructure, …) of the given socio-technical system, as well as an analytic mapping of stakeholder perceptions, strategies and interest become integral parts of the design process. Socio-technical systems can be seen as semi-coherent aligned system, but closures will always be relative and temporarily: '*tensions and mis-alignment may (temporarily) exist between element, which create windows of opportunity for wider change*' (Kemp et al 2012:16)

In a dynamic perspective, the notion of 'technological regimes' has been introduced to emphasize the social embeddedness of innovation (and design) processes.

A technological regime is the rule-set of grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructure (Rip/Kemp 1998: 338). Regimes are "*dominant practices, norms and shared assumption that structure the conduct of private and public actors*" (Kemp/Rotmans 2001:7); we have 'normal' design and technology practices with path dependency and biased towards incremental improvement and system optimization.

Regimes are communities of actors sharing cognitive rules in terms of problem agendas, search heuristics and guiding principles (Geels 2004). Socio-technical regimes are social realities, but in the analysis of social practices/design practices it is important to include a hermeneutic understanding of, how the actors/designers perceive and motivate their actions with reference to a specific interpretation of the structural conditions (Giddens 1884).

The notion of technological regimes provides an understanding of the general framework structuring design practices, but we need an understanding of specific design situations. For this purpose we introduce the notion of "design places". *Design spaces are specific situated configurations of networks of actors, specific interpretations and discourses and structural conditions in terms of institutional and material interdependencies, all structuring design practices* (Holm et al 2010:126) (see below).

The challenge of sustainable design is to change these regimes and design places and that becomes a project of meta-design (see below) concerned with regime transformation and the constructive formation of alternative design spaces in order to establish new configurations of actors, agendas and institutions enabling new openings for sustainable social practices.

CHANGING SOCIO-TECHNICAL PRACTICES EMBEDDED IN SOCIO-TECHNICAL SYSTEMS

Establishing reconfigured socio-technical systems will rely on change in our social practices – and successful strategies for intervention in established socio-technical system will depend on an understanding of how practices emerge, reproduce and changes (Shove/Walker 2010). We need to understand the dynamics constituting the persistence of social practices in order to enable deliberate change to more sustainable practices (Scott et al 2012). Attempts to establish alternative configuration of personal mobility will fail, if we do not understand how the alternative configuration can be socially constituted.

Our practices are composed of specific configurations of interconnected elements. Reckwitz defines practices as *"a routinized type of behaviour which depends on the specific interconnectedness of many elements, interconnected to one other: forms of* ***bodily*** *activities, forms of* ***menta****l activities, '****things****' and their use, a background* ***knowledge*** *in the form of understanding, know-how and notions of competence, states of* ***emotion and motivational*** *knowledge"..."'a block' whose existence necessarily depends on the existence and specific interconnectedness of these elements, and which cannot be reduced to any one of these single elements"* (Reckwitz 2002:249).

Shove (2008:9) suggests a more straightforward understanding of practice as a bundle of three elements: '*material artefacts, conventions and competences*', where materials include artefacts, technologies, spatial room, etc, conventions social and personal meaning and norms related to the given practice, and competences include understanding, knowhow, procedures, ... learned/acquired socially and in performing the practice.

We have every-day practices, which we take for granted, which become 'normal', but whether a practice is considered normal or appropriate relates to collectively established conventions of normality' (Shove 2003). Practices (e.g. of mobility) are individually performed in specific context and place, however, main elements of practices are constituted collectively and at a structural level. We have to operate with practice as both a structural coordinating entity and as performance (Schatzki 2001).

In parallel socio-technical practices are dependent on the system of provision – supporting (or restricting) specific schemes of practices (Shove/Walker 2010).

Taking mobility practices as a case, these practices are embedded in socio-technical systems with a high degree of path dependencies. Mobility can be considered a special case. We do have a specific linkage of 'the structural' and social practice, in terms of a spatial specificity e.g. specific accessibility to mobility options (infrastructure, public transportation, ...). Social practices and the specific local configuration of mobility systems cannot be separated and design as interventions have to address both sides.

Part II: Intervention in socio-technical systems and practices

Intentional design for sustainability involves an reflexivity on the criteria of sustainability and 'ecological literacy' of designers, understanding interaction with ecosystems and streams of material (Stegall, 2006), but it also involves a knowledge of 'metadesign'; that design has to address processes of structural changes, changes of visions, discourses and institutions and configuration of alternative design places. Designers have to expand their scope and skills in order to become players in the formation of alternative design places.

Performing design for sustainability involves interventions in the design places (context of design practices), and reconfiguration of socio-technical systems and practices. Here we shall unfold the notions of metadesign and reflexive design practices addressing design places, while design as reconfiguration of socio-technical systems and practices will be unfolded and discussed in relation to the case study and in the final part.

Metadesign

On a general level Giaccardi has defined metadesign '*as critical and reflexive thinking about the boundaries and scope of design, aimed at coping with the complexity of natural human interaction made tangible by technology … metadesign deals with the creation of context rather than content*' (Giaccardi 2005:343).

Within design research metadesign has been used in a more narrow sense to denote 'a user-centred and participatory design approach' (Giaccardi/Fischer 2008:2). In their perspective: *The challenge is to create social and technical infrastructures that enable users to cope with the emergent aspects of reality and allow them, when needed and desired, to act as designers and be creative* (ibid: 2). The argument is that creating such structural conditions, allowing users to act as designers, and providing frameworks (not fixed solutions) for an integration of users can serve as a stronger design approach capable of coping with ill-defined design problems, supporting reflective practitioners and in general support design as a collaborative process.

Here 'meta-design' is limited to a second order design practice configuring structures for a participatory design process without questioning dominant regimes structuring (and restraining) the design process.

Opposed to this perception, we operate with a notion of (sustainable) metadesign as design efforts oriented towards deliberate change of the contextual framework of design practices, the intentional transformation of dominant regimes and the formation of specific design places, or defined positively; deliberate efforts to develop alternative design places.

It is a call for reflexive design practices critically scrutinizing generally hold convictions and socio-cognitive structures of regimes. It concerns the discursive structures, or as Wahl/Baxter (2008:72) phrases it: *Upstreams, in the immaterial dimension, the 'metadesign' of our conscious awareness, value systems, world-views and aspirations defines the intentionality behind materialized design.* Metadesign, however, are not limited to the socio-cognitive aspects (discursive struggles), but involves a scrutinising of all the elements constituting socio-technological regimes and specific design places.

We have to address the transition of socio-technical systems and practices at a structural level and as a meta-design of design spaces - a reflexive and deliberate reconfiguration of agendas/vision, actors and institutions constituting the contextual framework (alternative design place).

DESIGN PLACES

Defining design as situated and inscribed in specific contextual framework is not new to design studies.

Buchanan (1992) operates with four broad areas of design: *design of symbolic and visual communication, design of material objects, design of activities and organized services and design of complex systems or environments for living, working, playing, and learning (p 9ff)*, identifying them as '*places of invention*' having their own kind of design practices, but also being interconnected (e.g. design practices exploring objects as part of larger systems and environments). They are subject to processes of conceptual repositioning resulting in a diverse set of 'placements' having boundaries to shape and constrain meaning. Placements in this respect provide contexts – and applied in specific situations, to problems in specific circumstances, Buchanan perceive them as interpretation structures and as sources of new ideas and options.

Based on this understanding, Buchanan (1992) introduces '*the doctrine of placement*' as a way of inscribing design practices; holding that designers, both as communities and individually, develop set of placements, which become their (personal) creative conceptual space. He holds that an understanding of designers as operating in 'placements', positioning and repositioning themselves within them, is vital to understand design processes, in particular when unfolded on 'wicked problems'. We need to operate with specific placements, defined in specific situations and circumstances by the involved in the design process, as an intermediate setting and framework for design processes.

The objective of Buchanan is to understand the creative processes of design; in this endeavor there has been a focus on the cognitive framing, mental processes of designing. By introducing the notion of design places we want to take in material and institutional setting as equally important constitutive elements in the 'space' which structures design processes. In doing so, we understand the design processes as embedded in design places, which are enacted in a duality of structural realities (material, institutions, collective conventions, …) and interpretive and selective processes.

Operating within a design space involves knowledge of the interdependencies and an understanding of how specific interpretations or translations of environmental/sustainable challenges in combination with expectations (related to specific technologies, such as electric cars) construe a set of actors, technologies and objectives, in the specific technology field (Raven/Geels 2010). Design in this perspective takes the role of framing actors´ needs and aspirations (in relation to technology options), and to translate various positions and ideas into a specific technology field. Framing is especially of interest in sustainable design as it exposes new ways of making mental models of products and technologies that fit to everyday life experiences (Lidwell et al. 2003) It can involve the association of BEV to Corporate Social Responsibility (CSR) programs or framing rail-traffic as part of integrated mobility services (not just trains on time).

An integral part of this process is the formation of local niche projects and design of socio-technical projects designed to enable processes of learning, building of network and experience based expectations (Brown/Vergragth 2003, Raven/Geels 2010).

META-DESIGNERS

'Metadesign' denotes a dimension of design practices which always has been part of design processes. In designing new socio-technical solutions – integrating new stakeholders and making coalitions supporting a given design has been an integral part of the design process (e.g. making the municipality of Copenhagen a supportive player in a car-sharing system or influences the tax-system on taxies). In general deliberately work for formation of a new institutional framework, where BEV makes sense. Metadesign in this perspective is a question of creating new networks/coalitions of actors and institutional frameworks. Or more precisely: The specific design efforts shapes the specific coalitions of actors supporting and relating to the project, while metadesign concerns the framework conditions enabling the coalition of actors and the enacting of the anticipated design.

In this respect we share the perception of Giaccardi/Fischer (2005): Metadesign concerns the development of structure enabling the participation and development of competent actors in enacting the design. However, the limitation of his approach is the lack of reflexivity – designing for sustainability has to challenge the existing dominant regimes structuring unsustainable practices.

Undertaking metadesign – deliberately seeking to influence the framework conditions of design is a prerequisite in designing for sustainability! Designers have to engage in the development, challenge and transformation of 'erratic' design spaces and deliberately seek to shape alternative design spaces. This implies that designers should build on analyses of the addressed socio-technical systems, identify and understand how they constitute 'negative' structural conditions and by this effort enable a critical production/design practice. Taking the dominant traffic system as an example, we depart from a 'non-sustainable context' – we need to be reflexive and challenge the context.

PATHWAYS OF TRANSITION

Seeking openings and alternative solutions involves an assessment of options and pathways of transition. Alternative solutions can be analyzed and assessed from a fit and stretch perspective in two dimensions: their functionality in user context (how they fit with or stretch existing user practices, e.g. how new mobility services fit with user expectations on flexibility) and the property or the technical form/design (how they can be incorporated in existing technology platforms (fit) or are demanding new technology platforms (stretch), e.g. integration of BEV in existing infrastructures) (Geels/Kemp 2012, Dijk et al 2013). It can also be described as system improving (fit) or system changing (stretch) pattern of the design solution (Dijk et al 2013).

In achieving system changes we may operate with pathways holding different scope and dynamics of transformation (Geels/Schot 2010):

- *Transformation* when regimes adapt as response to new agendas/changed external pressure
- *Deconstruction/reconstruction*, when major external pressure destabilizes the regimes and demands a reconstruction based on new constellation of the regime elements
- *Technological substitution*, when new technologies have developed to a level allowing them to replace the existing technology platform of the regimes
- *Reconfiguration*, when new technologies have been adopted and trigger (demand) the development of a new structure of the regimes

Introduced as archetypes of transition pathways, they can serve as a conceptual tool to reflect on the ‘radicality’ of the changes and on the character of the transition processes related to introduction of alternative technologies and solutions. Looking at specific processes of sustainable design (such as the case of electrical cars) we may find aspects of all four transition pathways.

PART III: DESIGNING MOBILITY – URBAN MOBILITY SYSTEMS BASED ON ELECTRICAL VEHICLES

The specific case is the design of an urban mobility service system based on battery electrical vehicles in an intelligent car sharing system (cleardrive.dk, Copenhagen). It is a study of the early formative stages of a design process – giving a focus on the project's structuration of design spaces through its interpretations and intervention in the socio-technical traffic system.

The design of the electric vehicle sharing system exemplifies a design process, where a company in interaction with actors from the transport industry, the electric vehicle industry, the political system and potential customers seeks to design a mobility system replacing fossil fuelled vehicles with electrical vehicles in order to reduce pollution and urban congestion.

MOBILITY SYSTEM – THE SPECIFIC CONTEXT

The car based mobility-system is an example of a non-sustainable socio-technical system. The main problems concern environmental problem, use of limited resources/fossil fuels and health problems. The focus has been on limitations on harmful effects by the introduction of demands on emissions and fuel efficiency. This has not reduced the total energy use and related CO_2 emissions (Energistyrelsen 2013).

Transition to electrical car based mobility-systems has emerged as a central technological option, and in Danish (climate) policy programs, promotion of electrical cars is identified as one of the pathways to reduction of CO_2 emission from transportation. The Danish programs include tax-exemption of Battery Electric Vehicles (BEV) and co-funding of experimentation (Budde, 2012) to encourage the uptake of BEV in Denmark.

The Danish programs have had (un-realistic) high expectations on the development and diffusion of BEV. Central authorities and municipalities have, through tax-exemption, free-parking concepts, and support to test and experimentation, meta-designed a design space for electrical vehicles, based on the expectations that market actors could ensure a fast propagation of BEV. These expectations have not been met. Main reasons have been misfit with reigning mobility practices/expectations and lack of infrastructures, combined with the limited driving range of BEV (e.g. Budde 2012). The over-all impression among potential adopters is that BEV is an un-mature and troublesome technology, which is difficult to integrate in the scheme of everyday life. On a general level, the Danish programs have adopted a strategy solely addressing the BEV as a technological innovation opposed to strategies perceiving the transformation as integrated changes of both technology and mobility practices (see Dijk et al 2013).

The Danish strategy for development and diffusion of electrical vehicles provides, together with the Danish regimes of automobility and transportation, a specific design space, within which market actors can act strategically, either by taking advantage of the framework or changing it.

The Danish regime of automobility sets very specific conditions for transition. Its main characteristics are a high taxation (a registration fee ranging from 105 to 180 % of the price of the car) combined with annual fees favoring small and energy efficient cars. The regime of transportation has been dominated by a neo-liberal market approach and limited political support for investment in transforming public transportation – public transportation has been subject to recurrent debates on failed projects and lack of ability to deliver services and efficient operation. In combination this establish a vigorously defended 'right of automobility' – a strongly held position, which was displayed in a heated debate, and final rejection (2012), of the project of establishing a toll-ring in Copenhagen. We have strongly entrenched private car use practices, also held rigid by the commuter society, mobility practices related to summer resorts, etc.

The regimes of transportation and automobility function as a selection environment. The regulation and institutional framework of the taxi-system of Copenhagen can be an example. Taxi could be an option for introduction of BEV – but it would take a remake of the system or a readiness to bypass established practices to enable experimental projects (see textbox – Taxi). Another example of path-shaping regulation is the limitation of the Danish tax exemption limited to BEV, which rules out hybrid cars as a pathway to have mobility based on electricity.

BEV-Taxi in Copenhagen

Attempts to introduce Taxi-services based on BEV have experienced two major problems related to the regulation

- Taxies are already subject to tax-exemption rules (no benefit of adopting BEV)
- The taxi-branch is subject to local regulation tending to protect the interest of firms and drivers within the branch. Obtaining a license for a Taxi-firm in Copenhagen requires more than 10 years documented Taxi-experience (rules out new alternative and experimental projects and firm)

So far central and local authorities have rejected to deviate from this regulation

The Danish design places of BEV

The major BEV project in Denmark 2011-2012 has been the Danish Branch of the 'Better place global' project, 'Better place' has made an attempt to address major barriers for the uptake of BEV. It introduces a technology platform combining exchangeable batteries in the electric cars with an infrastructure of exchange stations to meet the main barrier of BEV: the short driving range. In addition 'Better place' operates as a risk-taking intermediate agent; the company keeps ownership of batteries (lifting the risk of battery lifetime and technology obsolescence from the user) and it negotiates packages of power supply (Budde 2012).

The project is a major systemic effort to provide infrastructural conditions for BEV mobility. It is based on a battery technology platform developed in cooperation with Renault; so far the only car producer, who can deliver cars with this specific battery system adapted for the exchange stations. The Danish project is based on a co-operation with the energy company, DONG (minority shareholder in the Danish affiliate of ‘Better place global’). From their perspective, BEV using ‘intelligent charging’ (charging when energy supply is affluent) holds the potential to be an important part of the future smart grid.

The project ‘Better Place’ is in line with the Danish program of a market based diffusion. The roll out of an infrastructure with battery exchange stations should meet the problems of driving range, and allow BEV to become an alternative to traditional internal combustion engined (ICE) cars for private car users. The concept of Better Place as such is basically a technology substitution, a transition pathway based on a fit with the prevailing private car use practices. In this respect it represents a project adapted to and reproducing/consolidating the prevailing Danish BEV-design place.

CLEARDRIVE

The BEV-project of Cleardrive introduces another route. It has defined the project as the formation of an urban mobility service system, where car ownership is replaced by access to a mobility service based on BEV and integration with public transportation – an integrated intelligent car sharing system. It represents an alternative to the existing Danish strategy for electric vehicles. Thus Cleardrive in parallel to the development of the system has to engage in metadesign processes in order to influence the development of the specific Danish design place for adoption and diffusion of BEV.

Cleardrive grew as a project idea from a perception of a new opening in the political agenda (e.g. in the wake of the buildup to COP 15 in Copenhagen) and a potential paradigm shift in mobility based on BEV. The team of entrepreneurs establishing Cleardrive had their experiences (and resources) from the paradigm shift of developing IT-platforms for internet-based music services, and in the electric car technology they saw a parallel challenge: a shift from product to service waiting for an intelligent platform, including a supportive IT system.

Cleardrive is a ‘project-organization’ devised to elaborate a business case of BEV. In this role, they have undertaking the project to develop a dedicated concept of BEV- mobility system for central Copenhagen urban area, and as networking entrepreneur they are seeking to build alliances, establish business relations and raise funding for the project. In parallel they act as an analytic think-tank engaging in consultant projects and international cooperation with similar urban mobility projects.

Cleardrive has from its start in 2011 been working with the development of a concept for the ‘Copenhagen project’, including development of the related IT-system. The project is in a formation stage, but Cleardrive is (March 2013) operating with an anticipated launch of a full scale project August 2013 (Cleardrive 2013). In the following analysis, we shall present key elements in the design process up till this stage. The main steps have been redefined 'strategic expectations' for BEV, development of technical concept, building of coalition of proponents and turning the concept into an operational project (funding and customers)

CLEARDRIVE – STRATEGIC EXPECTATION OF BEV-TECHNOLOGY

The core step has been a redefinition of 'strategic expectations' for BEV based on analyses of the present mobility system and the potential of the BEV-technology. In contrast to 'Better Place', the project team of 'Cleardrive' did not define BEV as a 'technology substitution' project – a replacement of the private car. Instead they envisioned the BEV as the basic element in an integrated mobility service system. The main elements in this redefinition of 'strategic expectation' were

1. Building of an intelligent mobility service system based on BEV; the users should be offered mobility without ownership provided by.
    a. A high number of cars distributed within the area covered by the mobility project
    b. An IT-system tracking the car-fleet and giving clients 'Smart-phone-based' information on availability and (energy) status of cars in the system
2. Provision of a) mobility service for business and public institutions and b) mobility service for private users without a car or as an alternative to the second car.
3. A first implementation as an urban mobility service; the mobility service is defined as flexible access (pick and ride concept) to mobility within a specific area (e.g. central Copenhagen)
4. Integration with other local mobility systems; a subscription should include integrated access to public transportation systems and access to Taxi-service (when no cars are available)

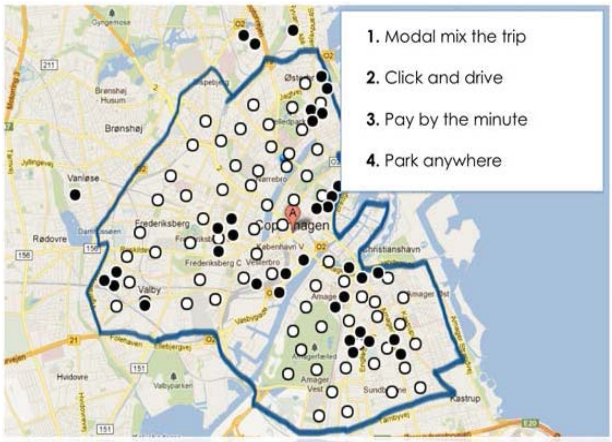
This 'strategic expectation' related to BEV deviates radically from the conceptual framing of 'Better Place'. Substitution of private cars is considered a too difficult entry point – BEV cannot at this stage cover all functional expectations, such as full flexibility and unlimited range, related to private car use, and the private car user practices are assessed as a too strong social practice to be challenged; this part of the Danish design place for BEV is considered a fixed condition. This assessment, that the market of private users was too difficult to develop, has led to a focus on business costumer in the first stage of implementation, combined with the provision of an urban mobility service. The belief is that this can provide a platform for diffusion to other user groups.

Departing from 'a mobility service concept', Cleardrive on the one hand seeks to take advantage of the specific design place related to urban mobility in Copenhagen (e.g. linking to public traffic systems (see below) and Taxi), on the other hand it attempts to redefines the design places by the redefined 'strategic expectation' – it introduces a new agenda and interpretation of BEV. This redefinition takes place as an interactive negotiation with local actors and actors of the mobility system – aimed at the formation of a ‘technology coalition’.

DEVELOPMENT OF THE TECHNOLOGICAL CONCEPT

The definition of ‘strategic expectations’ and the development of the technological concept cannot be separated. The expectations defined in the process are related to an assessment of the potential of the BEV-technology and how an IT-platform for the service could be developed in the specific context of Copenhagen.

The core idea of the concept is a provision of flexible access to mobility by placing a high number of cars within the covered area. In a first roll out of the concept, the project plans to place 150 BEV in central Copenhagen (Cleardrive 2013). The cars can be used outside the designated area, but have to be delivered within the area. Users can use their Smart-phone units to track free cars and use the Travel Card or smart phone as a key to pick up the car. Central units collect cars for charging, cleaning and service, and replace them (optimizing the mobility coverage). The project will take advantage of parking lots reserved for electrical cars and for car-sharing.



Figur 1: The cleardrive-concept - pick and drive. Illustration of the concept: ○ free cars ● occupied. Source: www.cleardrive.dk

A number of European cities have implemented such intelligent car mobility service systems. Most of these are based on traditional vehicles. There are two big European BEV sharing systems which have emerged in recent years. Daimler Benz has become a very important actor in urban car sharing systems and they have developed the system of Amsterdam (Car2go) based on small VEB (An adapted version of the Daimler ‘Smart’ concept) designed to provide an alternative flexible urban transportation system utilizing an urban charging infrastructure established by the City of Amsterdam (Car2go, 2013). The other major BEV-based project is in Paris, Bolloré Bluecars. It is a result of a public private partnership, where the industrial group Bolloré, with a basis in based battery technology, has developed their own charging infrastructure and uses the Italian produced bluecar (Autolib, 2013). In comparison, the ‘Copenhagen project’, is based on battery driven middle-sized electrical cars with centralized charging facilities, due to their focus on the business segment.

The concept of urban mobility service system rules out a piecemeal implementation. If it is going to succeed, it has to start with a critical mass (estimated to 150 cars to cover central Copenhagen). It also rules out the idea of a general (national) coverage; this has to be met by cooperation with other mobility providers (e.g. rental car companies).

The technological core of the project is (besides the BEV) the IT-platform (central management and a communication system from the cars) and user apps devised to keep track of and managing the car-fleet and to offer an interface to the customers. In addition the IT-system shall enable integration with other traffic systems. In the ‘Copenhagen project’ it includes an ambition of an interface to a national traveling system, ‘the Traveling Card’ (Rejsekortet), both to enable a seamless mobility (inter modality) including Cleardrive cars and public transportation and to enable the use of the traveling card as key in the cars.

For business customers, Cleardrive offers a dedicated mobility service product ensuring a number of available (and ready) cars at the companies address in business hours. The system ensures that it is only the employees of the company, who can ‘see’ the ‘company cars’ in the system, while they have access to the full fleet.

DESIGN PLACE – INSTITUTIONAL FRAMEWORK AND NETWORK

The configuration of the ‘Copenhagen’ Cleardrive concept to some extend reflects the specific national and local framework conditions; tax exemption on BEV and favorable parking conditions (parking lots reserved for BEV combined with no parking fee for BEV and car-charing vehicles on the street) were important preconditions for the ‘pick-and-ride’ concept based on a BEV fleet. The project, however, have been dependent on local negotiations ensuring a continued access to sufficient and centrally placed parking lots, including privileged access and contract with parking houses for the service centers.

On a more general level, the project in its negotiations and interaction with the public authorities has been able to link the project to local strategies on climate and mobility. As a specific project, turning general aspirations into practice solution, it both have met policy interest in implementing a green development and fitted into an aspiration of marketing Copenhagen as a ‘Green city’. In the process the Cleardrive project has been able to subscribe to established (local) discourses, but in its interaction it has also co-produced an alternative ‘strategic expectation’/vision/imagined future for urban mobility. The ‘Copenhagen project’ could benefit from framework conditions and local agendas, while the ’Taxi project’ on the contrary failed to get the needed changes in the institutional framework (see above).

The ambition of integration with public transportation systems (intermodality), to provide integrated mobility (also including public systems of urban bikes) meets structural constrains. The public transportation companies have, as a consequence of regimes of tenders and ‘new public management’, adopted strategies focusing on their core services (and with limited efforts in developing new intermodal services). They have taken interest in the Cleardrive project, however, but from the perspective that project can generate traffic (e.g. attract business customers, see below). A more active interaction could have included focused efforts to develop seamless shift between different transport technologies – at this stage, however, this has been limited to a planned integration of the Cleardrive project in the travelling card (Rejsekortet).

Cleardrive relies on the ability to attract business customer as a short cut to obtain a critical mass. In this effort they have the challenge to make it a sound and attractive business concept and to meet the expectations of business travelling. It implies an ability to link to both operational and CSR company programs, and in addition to have an attractive package to offer from the perspective of the employees. This can be tricky because free cars for the management level often are an important part of the work contracts for this segment of employees.

At this stage, before having an operational project, the main impact on the specific design place has been a reconfiguration of actor relations and agendas by presenting an alternative 'strategic expectation' for adoption of BEV-mobility. This involves the inclusion of public actors, transportation actors and private business actors as part of a network.

Implementation - turning concept into project

Cleardrive plans to start operations in August 2013 building an independent capital fund to run the project (Cleardrive continues as a project company, specialized in delivering and operating the IT-platform of the system and deliverance of similar systems to other cities).

A central part of the design process is to establish a close relation between financing and customers in order to construct a basis of dedicated customers. They need to attract funding for the investment in the car-fleet (a capital fond of approximately 1.5 million Euros is required to start up). The idea is to attract business customers that are willing to invest in the project. Cleardrive has made a business prospect (elaborated by an independent consultant) showing, that business partners could join the project (by investing in the initial funding) and based on reduced costs to transportation could have a profitable project - in addition to the potential public relation value of the project.

Part IV: Discussion and conclusion

Alternative design place for BEV

Cleardrive is designing a BEV-based mobility service as a business case taking advantage of the general programs of promoting electrical vehicles. Introducing BEV-based urban mobility services could been seen as a public infrastructure project, as is the case in all-electric mobility service project (Car2go) in

Amsterdam, where the Daimler concept of BEV car-sharing system is based on public funded network of charging stations, infrastructure, and the project in Paris (Bluecars), which is backed with public funding.

The design of the Cleardrive project could be seen as part of a reconfiguration process (metadesign) leading to the development of a new urban mobility system integrating intelligent car-sharing. BEV could be the backbone technology of such a system, but it could integrate a variety of cars designated for specific needs (round tours trip, transportation of goods, …).

The fact that Cleardrive is not part of a public driven transition project implies that the project has had to operate within the confines of the existing regimes of automobility and transportation providing a specific design place for BEV. The design process of Cleardrive in the ‘Copenhagen project’ has been a combination of navigation within the design space at hand and an effort (metadesign) aimed at redefining an alternative design space and reconfigurating of the socio-technical system of mobility.

This duality – adaptation and transcendence - is manifest in relation to mobility practices. Cleardrive refrained from substitution of the ‘all-purpose’ private car, but nevertheless has developed a mobility service with a high fit with the users expectations of flexibility (can be used instantly without reservation and independent of where you are and where you want to go). However, the Cleardrive project in the same moment has challenged perceptions of flexibility being related to private ownership and has offered a more sustainable mode of mobility. In this perspective the Cleardrive project can be seen as an intervention in the socio-technical system of mobility (shaping/designing new user expectations) – and a deliberate effort to develop an alternative design place (a metadesign act).

Looking at the Danish regime of mobility, and the specific design place it provides for the introduction of BEV, then ’Better place’ and ’Cleardrive’ represent two projects, which have made very different interpretation of and strategic choices in relation to the existing design place.

Better place (in alliance with DONG) has preserved and worked along the dominating mobility expectations with their attempt to offer an alternative to the private car; the strategy has been a roll out (taking a large up front investment) of a specific technology platform. It is a major (and expensive) infrastructural project aligned with the Danish strategy of diffusion of BEV. As a business project, it is highly dependent on having a rapid penetration of the private car market (Budde 2012).

Cleardrive has made a more radical interpretation of the technological options of BEV linking it to intelligent urban mobility service systems and establish an alternative vision of flexible urban mobility. It has involved a challenge of the existing design space of mobility in the city of Copenhagen – preserved by dominant actors pleased with the exiting rationalities and expectations for the future. With no big/public funding (beyond the general tax exemption), Cleardrive has had to make a rational assessment of the functional and technological capacity of BEV – seeking adaptation, but also seeking to outline an alternative pathway. It can be seen as strategic intervention in a field of high rigidity (economic discourse, entrenched mobility practices, …) by undertaking an experimental project involving a reconfiguration of agendas, actors and technologies, the deliberate effort to shape an alternative design place for BEV

DESIGN AND TRANSITION

Transition studies can be seen as having an implicit incorporation of design as part of technology development and transition processes. Some scholars have more explicit made an attempt to integrate design and elements from transition studies (e.g. Holm et al (2010) tracking a design process alternative product, Scott et al (2012) with a focus on changing living practices) making the argument that design studies should include a transition perspective. .

This study has taken the same line of argument. It has asserted that design for sustainability involves deliberate efforts to transform the structural conditions (regimes/design places) and the constructive shaping and facilitation of alternative design places. It has called for an expanded reflexive design practice:

- The notion of design place, understood as specific (situated) configurations of agendas, institutions, actors and technologies, has been introduced with the objective both to have a critical examination of existing context of designing, and to call for an attention on openings in specific local settings or of potential alternative design places (alternative combinations of agendas, institutional framework, actors and technologies)
- Metadesign has been introduced as a concurrent development of alternative design places and reconfiguration of existing (unsustainable) socio-technical systems. It is a call for a reflexive design practice scrutinising existing framework conditions of design and deliberate efforts to transform them to enable new more sustainable design practices. It involves such aspects as development of alternative (strategic) expectations/visions, actor-network and knowledge/competences.
- Metadesign of alternative design places and experimental projects within existing design places may be perceived mutual dependent processes. Experimental projects taking advantage of specific situated conditions are needed to gain knowledge of new options and enable the formation of new alternative design places. Simultaneously, strategic action (metadesign) is needed to shape new openings.

The notion of metadesign does not prefigure an understanding of the privileged designer. On the contrary, it is a call for a reflexive practice of designing, constantly reflecting on the context of designing. This even more in designing for sustainability – the complexity in obtaining more sustainable practice takes an ever ongoing reflexivity scrutinising outcome and direction of designing activities within prevailing design places.

The opposite question, how transition studies could benefit from design studies, has only been touched upon in this study. The work of Buchanan (1992) and Giaccardi/Fischer (2008), which have been included, may give some indication. Their inquiries addresses how we, confronted with indeterminacy and ill defined/wicked problems, may facilitate creative design processes and the inclusion of reflexive practitioners and how we may understand processes of creativity evolving when design is enacted in specific settings. Buchanan highlights design as acting in specific context from positions of placements: setting boundaries of meaning cognitive repertoires allowing creative and innovative way of acting. Here illustrated by 'the product to service rationality' informing the entry of Cleardrive in the arena of mobility in Copenhagen.

Design studies call attention to the creative element in transition, a line of enquiry which still has to be unfolded.

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How to understand (and support) non-ownership of a car?

Reviewing the case of Vauban in Freiburg (Germany): Individual choices versus social practices

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Abstract

Per 1,000 inhabitants of the Vauban-district in Freiburg, Germany, only 165 private cars are registered. How can this be explained? The various transport political measures that were implemented in this so called 'model district for sustainability' have been analysed before. But how do these factors interplay and which are most important? Are other factors than political measures and hard infrastructure important too? Inhabitants have been asked about how they perceive and weigh these conditions. Conceptually, we start from a socio-technical systems perspective and argue for the use of a particular practice theoretical perspective. But this perspective turns out to be very challenging in methodological terms. The main aim of this contribution is to put a nascent research design up for discussion. Some preliminary results of eight interviews are discussed.

key words

car non-ownership; urban planning; sustainable mobility; social practices; research methods

1. Introduction

Striving for sustainability transitions, many put their hope in a shift away from current lifestyles towards more sufficiency orientated lifestyles. Policies are sought to support such a shift. First urban planners aimed to support more sustainable lifestyles already in the 1990s. One aspect of urban lifestyles targeted in such policies is the use and ownership of private cars, which is not only responsible for significant shares in resource consumption and greenhouse gas emissions but also for other societal costs (space, living quality). It is assumed, that the perceived need of private car ownership is dependent on the extent to which people can move between home and places of work, learning, shopping, leisure etc. comfortably without a privately owned car. The distances between these places are crucial as well as the given alternative means to comfortably get there. Planners - e.g. of a new urban district – who want to support car non-ownership as an element of sufficiency oriented lifestyles, can therefore consider a) a particular land use regulation and lay-out of districts that possibly fosters the proximity of places between which people will frequently travel and b) a good equipment with public transport, cycle lanes, pedestrian areas etc. to support the attractiveness of alternatives to travelling with a private car. But can such infrastructural change also bring about behavioural change?

When plans were developed in the late 1990s to convert the Vauban area in Freiburg into a district for 5,000 people, civil society actors lobbied strongly for developing a “model district” of sustainability, including an ambitious ‘mobility concept’ besides plans for energy efficient building, citizen participation etc. (Sperling 1999). The design of the district, they demanded, should enable and support a car-free life with all possible means. They were largely successful. In consequence, parking space was limited to two parking houses at the fringe of the settlement plus some space along one central avenue, and all other streets in the districts’ core were designed primarily to support a non-motorized life.

Today, **per 1,000 inhabitants of Vauban, only 165 privately owned cars are registered** (1.1.2012). This is 50,7% less than Freiburg average (Freiburg 2012) and only a good third of the German average of roughly 411. So it seems that yes, behavioural change - or at least a clearly different behaviour compared to that of populations in other parts of Freiburg and Germany - can be achieved under the conditions that are given in Freiburg-Vauban. **What exactly is responsible for this low rate of private car ownership?** Or, more generally speaking, what are the conditions that enabled more sustainable mobility practices to occur in this district? Experiences from other cities and even from other districts of Freiburg show, that the provision of good access to a tram-line and to cycle lanes are not sufficient to achieve similar results. What other factors may be involved too in making Vauban a place where many (also wealthy) people enjoy life without individual car ownership?

Of course various factors have to be considered that make the district special. Knowing that this district is renowned world wide as ‘sustainability model district’ (Scheurer & Newman 2009; Broaddus 2010, Scheurer 2001), we may first assume that the low rate is the result of a successful policy. In fact there was a very ambitious ‘mobility concept’ developed during the mid 1990s and largely implemented thereafter, including the blocking of transit, the imposing of walking speed and priority for children on most minor roads, the reduction of parking space to parking houses at the fringe of the district, the provision of excellent conditions for cycling and pedestrians etc.. An important success factor might furthermore be, that this has been developed and fought about in a process involving many engaged citizens and experts in the framework of a particularly participatory planning process (Sperling 1999) and that it was embedded in a comprehensive approach to fostering a sustainable life (including aspects of energy consumption, green sanitation etc.).

Consequently, lifestyles performed in the district have been subject to two larger studies based on surveys with inhabitants (Brohmann et al. 2002; Nobis 2003b). These studies, largely quantitative in nature, cover the situation at a very early stage of the development. At the time when they were conducted, less than a fourth of today’s population was living in the district, and those people daring to settle in the ‘model district’ very early without knowing how it would further develop might have been followed by many more ‘ordinary’ people today. If we want to understand today’s pervasiveness of a car-less life in the district, we have to gather fresh data. And we probably need primarily qualitative data in order to answer our questions. In recent years, the district has also attracted the interest of a qualitatively working sociologist, who studied conditions for the emergence of sufficiency oriented lifestyles (Westermayer 2011). Applying a social practices perspective, he focused on the use of mobile phones. His findings (comparing a Vauban population with another population in Freiburg) might provide interesting background information and touch stones to check our findings on mobility practices.

The ambitious transport policy of Freiburg in general – probably another important context - has been described in detail and as ‘best practice’ (Buehler & Pucher 2011, Beim & Haag 2010). But, in order to really understand why these shifts occurred to this extend, we should not restrain ourselves to the study of the various *policy measures* that have been applied. We believe it is important to also ask: **How are the given conditions *perceived* and how are the resulting practices *explained by the various inhabitants themselves?***

Sustainable mobility is a very vividly debated topic in Vauban since the first households moved in (Nobis 2003a; Nobis & Welsch 2003). This has often been related to the fact that for the first time in Vauban, some **institutional innovation** allows to bypass a sentence of the building legislation which in principle requires that for every housing unit built parking space for one car is provided, regardless of whether the respective household uses a car or not (Brohmann et al. 2002:32). Due to this scheme, households not owning a car can join in an association and provide it with a certain amount of money for keeping some land (at the fringe of the district) ‘in stock’ for the case that many previously car-free households get in need of parking space at some point of time in the future. Only due to this provision, the administration was enabled to allow for fewer parking lots than housing units to be built. This means for car-free households, that they can save the largest share of the money usually spent for building an obligatory parking lot (often invisibly included in the monthly rent), i.e. in the case of Vauban the capital costs of roughly 17,000 EUR. This incentive, making usually externalized costs of car ownership visible, is not insignificant, as occasionally surfacing conflicts about free-riding show (some households continuously enjoy the benefits of their claim to be ‘car-free’, although frequently using a private car). Note that this model aims at providing the whole population of a large part of the district (some people owning a car and some not) with the various benefits of a limited presence of cars. This model was deliberately preferred over a model where all households of a defined area have to be (and remain as long as they live there) car-free households, as it has been implemented in parts of Bremen (already in the 90s) and later in Vienna (Ornetzeder et al. 2008).

This new **scheme for benefitting from being officially ‘car-free’** (i.e. to contractually agree not to own and regularly use any private car), which all households living in a larger part of the district (see figure 1) can freely opt in or out of as they wish, goes hand in hand with another regulatory feature: the declaration of many low level roads in the district to be a no-parking zone. The inhabitants of the same area are – when using a car - allowed to access their homes with them, but not to park them anywhere close, except in one of the two parking houses at the fringe of the district. By intention, their bicycle, the tram station, the cars of a car-sharing organisation and even a supermarket are in many cases closer to their homes than their private cars.

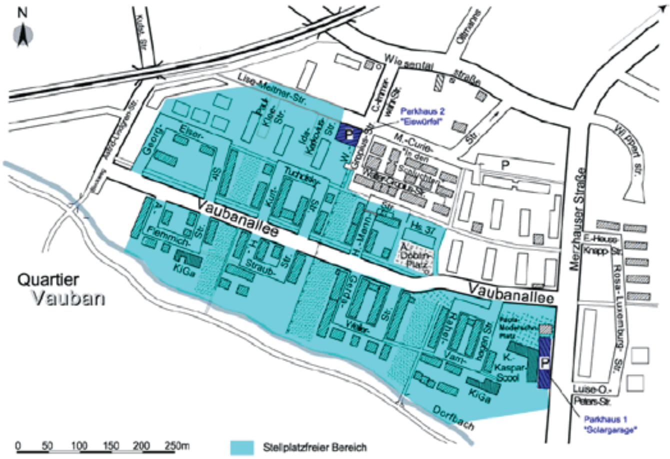

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Fig.1: In the blue area no parking space is provided except for ca. 420 lots in 2 garages (dark blue).

If urban planners wanted to reproduce 'the Vauban effect' of reduced car ownership elsewhere, I assumed from the beginning of our research, that we should study **the interplay of a) mobility infrastructure (providing alternatives to using and possessing an individual car) b) economic incentives (such as the special scheme for officially car-free households) and c) normative & cultural cognitive institutions (such as conventions about what mobility behaviour is seen as normal)**.

A core aim of this study is to answer the following research question: **How is the influence of the various factors to be understood and weighed?** As an important way to answering this, we want to know first how the inhabitants themselves appreciate these factors. A major motivation behind this study is the assumption that once we develop a better understanding of the interplay of factors in this case, it might help us also to improve our understanding of (and possibilities to support) **'sustainability transitions'** more generally.

2. Theoretical perspectives and analytical framework

Having pinned down our research question just above, we can reflect on an analytical framework that would cater for all our interests (a-c).

The case of the car-free inhabitants in Vauban seems to be an interesting example of a sufficiency policy - although it needs to be finally assessed to what extent the low level of car-ownership really is a result of the intentionally applied policy measures. The infrastructural decisions (on tram-line, parking space allocation etc.) can be understood to be rather straight forward **political choices**. They were, however, negotiated in highly controversial negotiations between members of the administration, the city council and engaged citizens, of which many were organised in 'Forum Vauban', an organisation representing 'future inhabitants' of the district and including many engaged experts during the planning phase of the district. The 'mobility concept' developed by Forum Vauban for the future 'model district' can be understood as **a guiding vision** which envisaged a mobility situation in the district which would allow as many people as possible to optimally benefit from a car-free lifestyle. Such a guiding vision, comprising of various ideas and storylines, could have effectively aligned **a policy network** in the struggle over these decisions (to be formally taken by the city council and/or the city administration) and might have produced discursive hegemony (see Späth & Rohracher 2010; Späth 2012b for another example of such a process). It would be very interesting to better understand political and planning routines interplayed in this case with a 'bottom up' process of lobbying around a vision (or visions) of a district that supports a sustainable lifestyle. This, however, will not be the particular focus of this paper

Along the way, **institutional innovations** were developed. Our understanding why and how this happened might benefit from the approach of institutional entrepreneurship (Battilana et al. 2009), but this shall also not be at the focus of this paper. What might help us here, though, is the basic vocabulary provided by Scott in order to differentiate between institutions of different societal functions and grades of durability: 'regulative' versus 'normative' versus 'cultural-cognitive institutions' (Scott 2008:51).

On one hand, we wanted to explore the situation from the perspective of the inhabitants: What can we learn from their perception of the seemingly favourable conditions for a car free life in Vauban?

On the other hand, we deeply believe that sustainable patterns of production and consumption will not emerge out of an aggregation of individual choices alone. In order to support political measures that are possibly able to foster **sustainability transitions**, it is important to study the situation from the perspective of **socio-technical systems**: to study how **path dependencies** emerge (in fields mobility or energy) in an interplay of material and institutional factors (involving e.g. past investments and infrastructures, the setting of standards, canonisation of knowledge, societal expectations etc.). This interest and believe basically is what brings us scholars of Sustainability transitions together (Markard et al. 2012). During the last few years, it became increasingly clear that our conceptual framework, highlighting the long-term, multi-level dynamics of such socio-technical systems, deserves more of a political 'micro-foundation' such as via the detailed, context sensitive study of how discourse coalitions can be formed around guiding visions (Späth 2012a; Späth et al. 2012).

Another perspective, **practice theory,** shares that interest in how material aspects constrain and enable individual choices (Reckwitz 2002b; Reckwitz 2002a). As much as the so-called Multi-level perspective as a commonly used version of transition studies (Smith et al. 2010), the social practices approach also tries to differentiate factors influencing individual decisions along an agency-structure continuum. Since this perspective is reported to be of particular help in matters of sustainable consumption (Shove et al. 2007; Halkier et al. 2011; Hargreaves 2011), will it enable us also to better understand the low car-ownership rate in Vauban?

In recognition of longstanding efforts of Elisabeth Shove and Gordon Walker to make transition studies and the social practice perspective speak to each other (Shove & Walker 2007, 2010), and in line with recent efforts elsewhere (Hargreaves et al. 2012), appreciating the complementarities and important differences, like the different entities of analysis (social practice vs. socio-technical regime) we want to explore the applicability of a particular practice theoretical approach for resolving our puzzle.

Shove and Pantzar suggest to study the emergence of new social practices as a process of "the active and ongoing integration of images, artifacts and forms of competence" (Shove & Pantzar 2005:43).

3. Methods

The question how various factors are perceived and how they actually influence people's behaviour calls for direct interaction with inhabitants of the district. We therefore started to interview 'ordinary inhabitants' of Vauban. The first five **interviews with inhabitants** were semi-structured and aimed to explore preliminary hypotheses as well as test interview questionnaires.

Detailed research questions are: How do people weigh the importance of the various factors influencing their decision to live with/without a private car? What where decisive reasons for purchasing a car or terminating car ownership? Do people who own a private car perceive of the enabling or constraining factors (in Vauban compared to other places they know) differently than those who live without a private car? Did they observe mobility practices or conventions particular to Vauban?

Our **sampling strategy** needs to reflect the exploratory purpose of our study and that we need to understand the perspectives of very different groups in order to get a rich picture. So far, we interviewed members of households a) who possess of a private car, b) who share one car privately with another family and c) who do not possess a car at all. Four of the five households are members of a car-sharing organisation. With regard to household size, we so far interviewed only members of relatively large families (2 families of four, 2 of five and 1 of six) which are strongly over-represented among the population in Vauban (compared to other districts in Freiburg and Germany) and particularly prone to car ownership. In order to get a plurality of perspectives, we interviewed of these families in two cases the father, in two cases the mother and in one case the 17 year old daughter. These first interviews (see results below) already pointed us to further questions and particular groups of people we might interview in order to answer them: How do people who moved away from Vauban perceive of the conditions that shape their choice of means of transportation in the new environment as compared to Vauban? How do particularly young people who lived in Vauban for most of their childhood and adolescence experience other environments when they move there? Are conditions favourable for a car-free life important for their choice of a place to live in? Besides 'ordinary' inhabitants, we also interviewed three key experts so far who were either involved in the early development of the innovative institutions (mobility concept, waving of the parking-lot obligation, car-sharing) or in their current administration - in order to fully understand the development of the mobility related institutional context in Vauban.

With this so far very limited data base, we are of course far from saturation. Many **more interviews** need to be conducted. A full coverage of all inhabitants, which the comprehensive survey of mobility practices in Vauban aimed for in 2002 (Nobis 2003a) is not feasible, now that the population has increased from roughly 2,000 to over 5,400. For the very limited number of in-depth interviews we are able to conduct, a **purposive/theoretical sampling strategy** should ensure that particularly relevant groups are well covered. Relying on personal contacts and a snowball sampling strategy might, however, bring in a bias (e.g. towards people particularly inclined to sustainability issues). For this reason, the theoretical sample may be complemented with a **random sample** of inhabitants, addresses for which would be available from the municipality. However, this sample will never match the purposive sample in all criteria, since these criteria are way more specific than the specifications of the address data that we can create a random sample from.

In order to complement the individual perspectives voiced in interviews, it is of course also very fruitful to **analyse documents** (newspaper articles, brochures, city council minutes, pamphlets, websites etc.), which should ideally allow us to develop a picture of a local discourse on mobility in Vauban.

Being half way through the analysis of the first few interviews (see below), we can already conclude that it is very challenging to reconstruct the development of any social practice on basis of interviews. This might not come as a surprise, given that social practices are an entity of study external to individuals and that they deliberately comprise many factors that are not easily communicated or even beyond cognition for the practitioners (routines, things taken-for-grated etc.).

Focus group discussions are a methodological tool particularly suitable to unearth unconscious knowledge that is not easily accessed in interviews. The feasibility of attracting inhabitants of Vauban to such discussion rounds has been explored in the first interviews. It seems that participation will very much depend on how attractively the issue for discussion will be presented to the potential participants. To offer material incentives for participation (vouchers for the cinema or the like) seems not to be as crucially important. Also to meet the self-interest of the potential participants (learning something, having a good time with a particular crowd of people) seems to be much more important than pleas for solidarity and support of a generally beneficial research project.

In order to increase the scope and liability of the analysis, it would be good to triangulate the data obtained via interviews (on perceptions, which necessarily are filtered by reflection and communication) with **direct observations** (e.g. of mobility practices connected to shopping, leisure, etc.). The author was living in the centre of the Vauban district from 2001 to 2003 and is living there again since 2009. This position makes it impossible to NOT daily observe characteristic mobility behaviour. To make such observations methodologically fruitful, it would be necessary to conduct them in a systematic way (in various places, at certain times etc.) and document the observations in adequate ways (e.g. by photographing, mapping). An interaction of 'insiders' and 'outsiders' might be particularly fruitful and efficient when it comes to fine-tuning the methodological approach and to analysing the qualitative data gathered. Also asking selected inhabitants (with/ without a car…) to run **mobility diaries** (in Vauban/ after moving away…) seems to be a promising strategy.

4. First, preliminary results

So far, only 8 interviews were conducted and a few documents analysed. These first interviews particularly helped to assess the methodological challenge that a practice theoretical perspective implies: From the perspective of an individual, (particularly if he/she is not familiar with sociological or even socio-technical concepts), what counts and what he/she can report of are particularly the personal motivations and rational(!) reasons of his/her choice. The respondents are reflective of their own choices and routines, but they perceive of themselves as largely acting independent from the practices of their neighbours. In multiple cases, interviewees made the point that they just continue practices which they had already performed before moving to Vauban, or that their practices did not change because of the particular framework conditions given here or through the influence of neighbours setting an example but because of other reasons like e.g. that the family had grown. Some examples, however, indicate that particular practices are developing in the interplay of performance and observation. One interviewee recognized that she once observed all skis of a family to be packed into a bicycle trailer for transportation to the train station and that she once learned how to bundle cross country skis onto a bicycle from observation. To borrow non-personalized monthly tickets for the public transport when needed or to share them with relatives living nearby is a very common practice. However, for the study of ‘social practices’ direct observation and focus group discussions seem to be much more suitable methods than interviews.

To get deeper and unearth hardly explicable factors determining ones actions (like routines, shifting preferences etc.) without inadequately manipulating respondents requires very sophisticated research methods and techniques.

The interviews also helped to solve a misconception that has shaped many earlier case studies and “best practice” reports from Vauban and which also influenced the original setup of this study: A strong focus on how policy measures and structural conditions may have produced the explanandum of course detracts from the possibility, that a reason for a large part of the low car-ownership rate in Vauban in fact could be related to personal preferences. The people living in Vauban are of course not “average people” (regarding their preferred means of transport) and the structural conditions making the district so supportive of a car-free life may have attracted them to the district, but are not necessarily *decisive* for their current behaviour. Many of the people particularly attracted to the district were living without a car also before and under much less supportive conditions. The widespread individual preference for a car-free lifestyle needs to be considered of course also as a variable that is independent of the conditions that the district provides for such a lifestyle, since it was given to a large extent in this population even before it met in this district.

With regard to the specific research question, the relative importance of the various factors, the first interviews also produced some productive surprise. Besides the deep grounded personal preference of a car-free life (that in many cases has been developed before moving to Vauban), interviewees unanimously highlighted two aspects which were part of the “mobility concept” for the district, but rather secondary ones to the very present features of the parking space allocation, the car-sharing facilities and the individual incentives for households to officially become ‘car-free’. These factors highlighted today by ‘ordinary inhabitants’ are: A) the proximity of most destinations of their every-day life (shops, friends, dentist, whatever) and B) the particular design of the public space (for pedestrians and cyclists), that makes it very attractive to travel by foot or bike and meet neighbours along the way.

Two of the first interviewees even explored the interplay of these two factors. Various qualities of the public spaces created in the district seem in fact to be very influential for the way people travel shorter distances and how they network (hence reinforcing the proximity of potential providers of goods and services they access). This holds not only for the lowest level roads (speed limit = walking pace) that are connecting the individual buildings with the higher level road system. To get them freed from parking cars has been one of the primary objectives of the mobility concept. But also wide spaces for the joint use of cyclers and pedestrians, providing plenty of space (e.g. allowing cyclists to circumnavigate people who block the road chatting away) are perceived as important for individual mobility practices (and social networking). Places that invite people to rest and sit, and the arrangement of places that people pass by in their everyday life in such a way, that they are likely to meet many neighbours, all contribute to a procurement of goods and services in great proximity and by foot or bicycle.

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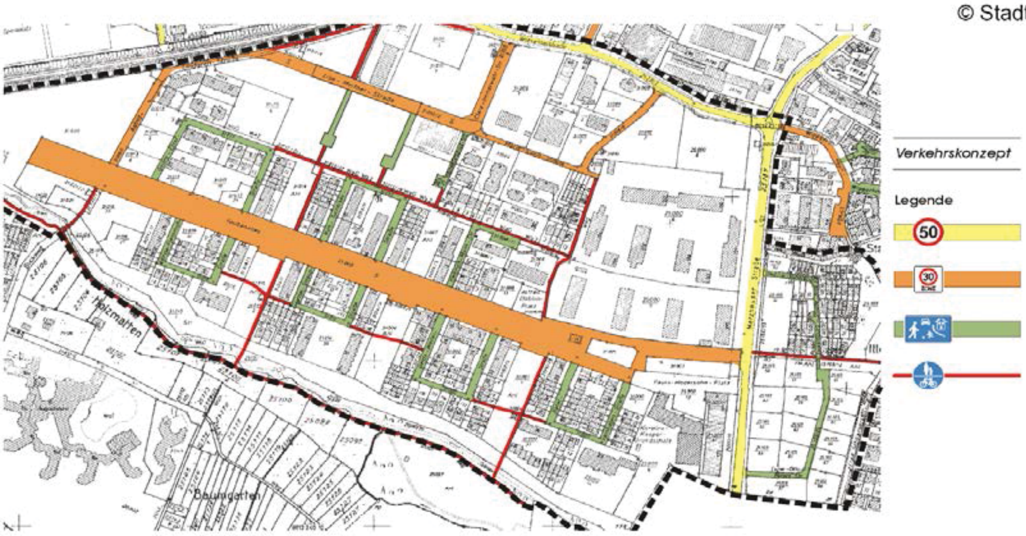

Fig.2) Road system: circular (to prevent transit) with max. 30 km/h (orange) or max. walking speed and priority for pedestrians (green) plus cycle lanes (red) plus a particularly wide alley.

Appreciating these two factors A) and B), actually complementing our analytical framework, should ensure that we get rid of any remaining bias towards any particular mobility infrastructures and economic incentives.

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Fig.3) Many public services (tram, bus, pre-schools, primary school, community centre, parks etc) and shopping facilities closer to the homes than the parking facilities.

Particularly due to our practice analytical approach, the perspective of children and youth who grew up in this district (the first families moved in around 14 years ago) seems to be of particular interest. If many appreciated it as increased freedom, that it is rarely necessary to be taken somewhere with a car, as one 17-year old interviewee describes, and if many of them are as little inclined to shifting towards motorized mobility patterns even when they move away from home as she seems to be, this would be quite interesting from a sustainability transitions perspective. Somehow contrasting with the expectation of some parents in Vauban (kids tend to do things differently than their parents) the only teenager we interviewed for example knows in total only one teenager (living somewhere else) who owns a scooter. In other parts of Freiburg, the possession of a scooter seems to be an obligatory status symbol for youngsters of a certain age. Our interviewees answer to the question whether she herself would be inclined to own a motorized vehicle some day in the future was: "Where should I go to with it? I am quite happy that I get everywhere I need to perfectly well with my bicycle". This reinforces the importance of the fact that the portfolio of destinations, that a person frequently travels to, can – in compact cities like Freiburg (220.000 inhabitants) – under certain conditions develop over the years in a way that the actual mobility needs fit very well with the options that are given by a relatively good system of bicycle routes, excellent public transport services and (as a fall back option) reliable car-sharing services.

The importance of the institutional innovation developed for letting car-free households benefit financially (on basis of costs avoided by building fewer parking places than the regulation normally would require) on the other hand needs to be critically analysed. It might be something very nice to have (enjoyed by 421 households, as by 31.12.2011), and instrumental in attracting particular people to the district, but it might be less often a decisive factor for the decision to live without a private car than one could expect intuitively.

The option to temporarily use a vehicle of a car sharing organisation was given already in the early days of the new district. Today, the districts population is particularly well equipped with cars to share. The major car-sharing organisation Stadtmobil alone provides 20 vehicles within the Vauban area, servicing 442 clients (19.4.2013) among the population of 2,336 households (1.1.2012) – presumably the world's highest ratio. This situation is both infrastructural and institutional in nature. The organisational model of membership based car-sharing has been developed in Freiburg very early in the late 1980s, when there were still very few comparable initiatives in other places. But even this condition seems to be less decisive today than one could expect. Several households explain that they use car sharing rather rarely and that they do not perceive the possibility to use a car anytime as a precondition for living a car-free life. May this 'downplaying' have to do with the fact that people are very much used to having the option? It may be more important for those people who just shifted from owning a private car to not owning one, than to those who practice a car free life for several years. It would be interesting to follow up on this with people who cancel their access to car-sharing without moving or getting a private car.

5. Conclusions

It has been healthy to experience in practice that interviewees really do not share my pre-occupation with social practices and what methodological challenges this implies. That they highlight the freedom of their individual choice, their independence from infrastructural conditions and from practices performed by neighbours can be understood as a necessary construct.

Conceptually, this, however, raises the question to what extent and how an approach, that starts off from the experiences and perceptions of the practitioners themselves is truly compatible with a social practice oriented perspective. To the extent that the latter tries to unearth also unconscious elements of practices like things that are taken-for-granted, that people get used to and do not consider, it poses challenges with regard to research design, methods and skills.

Unfortunately, we have not yet been able to broaden our empirical basis and to develop this very first, preliminary analysis any further than this.

We are still far from providing a ‘thick description’ of how people in Vauban perceive the factors which enable them to live a happy life without owning a car. However, I feel to be on the right track, conceptually and methodologically. The harvest of confirmations and surprises is - in my view - well balanced.

However, I would be very happy about any constructive feedback that the reader could provide me with, particularly in view of a fine-tuning that is possible before starting a more comprehensive (and hopefully soon funded) research.

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Mobility Transitions in Munich 1945-2012

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1. Introduction

In practice and in research there is at present considerable attention for the coordination of transport and land-use planning (Banister, 2008; Cervero, 1998; Curtis et al. , 2009; Dunphy et al. , 2003; May & Marsden, 2010). Switzer e.a. (2013) reach the conclusion that there has been considerable research carried out in terms of the steps to be taken and the policy to be adopted in order to realise coordination between transport and land-use planning as well as modal integration. However, the issue is that of how to tackle obdurate problems that arise in attempts to adapt both practices and the structures in which they are embedded - in other words to achieve a transition, is still unsolved (see Banister, 2008; Bertolini e.a., 2008; May & Marsden,2010; Tan & Bertolini (2010). At the same time research in planning (Valderrama & Vogel, 2012;, Bertolini, 2011; Kaufmann e.a., 2006, Cervero,1998, Tan e.a. (submitted), Bratzel, 1999; Kaufmann & Sasger,2006) and historical research about (transport)planning (Blanc, 1993; Schmucki, 2001; Mom & Filarski, 2008; Filarski & Mom, 2008) show that transitions in the transport and land use system (or 'mobility system': Switzer et al. 2013) have taken place in the past. In order to develop a framework that can help identify the dynamics behind these historical transitions, and help identify strategies for future transitions, Switzer e.a. (2013) focus on transition studies, an area of study where research has been carried out on the obduracy of practices as a result of the coevolution with dominant social (e.g. state and market institutions, discourses, norms, heuristics) and material (artefacts) structures (Geels & Schot,2007; Grin e.a. 2004; 2010; Rotmans & Loorbach, 2010). Although this conceptual instrument has proven useful to structure a discussion with stakeholders about barriers and opportunities for future transitions, it has not been tested for its worth in analysing transitions in the past. Second, we suggest that the framework still does not devote enough attention to the coevolution of practices and structure. First, we supplement the theoretical shortcomings of the framework of Switzer e.a. (2013) with a conceptual model of transition as the result of changes in structure in interaction with practices. Second, we apply this framework to an analysis of transformation of the mobility system of Munich where secondary sources (Cervero, 1998; Schmucki, 2001) suggest that transitions have taken place. Based on an embedded case study, hypotheses will be developed about why and how transitions take place. Finally, we make suggestions for further research.

2. Theory

Switzer e.a. (2013) present a heuristic framework based on Bertolini's (2012) interpretation of the transport land use feedback cycle and on the multi-level perspective (MLP) of transitions (see Geels & Schot, 2007). The result is shown in figure 1. In the model the three levels of the MLP can be distinguished: socio-technical landscape, regime and novelties, as incorporated in the components of the transport land use feedback cycle. The landscape is composed of long-term exogenous trends such as macro political and economic developments, deep cultural trends as well as demographic change and technological progress. We also consider developments in the mobility system at spatial scales higher than the urban region to be part of the landscape. The regime is the dominant configuration of the mobility system in an urban region and is composed of mobility practices, rules, artefacts and discourses. These are characterised by coevolution and are thus obdurate in nature.. Mobility novelties are also composed of rules, discourses, practices and artefacts, but in contrast to the regime these are instable, which requires continuous effort from novelty actors to maintain them. .

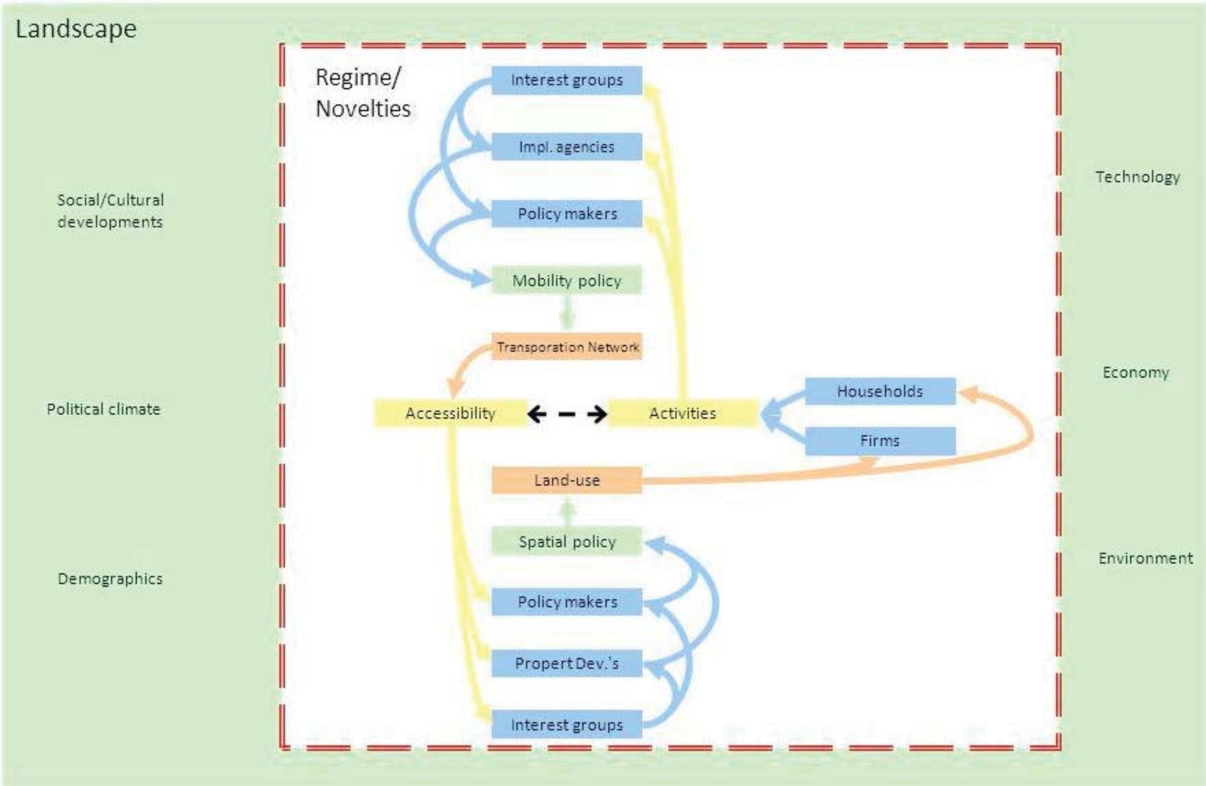

Figure 1: Heuristic framework of the mobility system (Switzer e.a, 2013)

The transportation network and the land use (artefacts) change slowly and seldom spontaneously. The reflexive actions of individual competent actors are important in this change. These are policy makers, property developers, transport implementation agencies, and interest groups (e.g. businesses, scientists and activists) with respect to mobility and spatial policies, and individual firms and households with respect to location and travel choices (together 'activities' in figure 1). All of their actions are influenced by structure in the regime and novelties (i.e. existing artefacts, rules and discourses), but can also be a reaction to expectations for the future, landscape developments, those in another systems or the actions of other actors. We consider 'policy'- both spatial and mobility policy – as developed by policy makers from government, but also other actors who directly exert influence on the development of land-use and transport networks (property developers, and transport implementation agencies such as public transport companies or highways agencies). Interest groups can influence the actions of these actors by lobbying, negotiation or providing new insights . Individual households and firms react to the availability and the accessibility of land resulting from these policies by making choices about where to locate and how to travel (by their 'activities') . The resulting location and travel patterns are, normally in aggregated form and including future expectations, interpreted in their turn by policy making actors when making their decisions.

2.1 Transition dynamics

Based on a discussion of various perspectives on change Switzer e.a. (2013) conclude that two general pathways can be distinguished: one that starts with novel practices in the regime that are subsequently defined and legitimated or can result in regime change with the further development of novel practices as a result; and a second one that starts with instability at the level of the regime (as a result of landscape pressure or tensions within the regime) whereby space for novel practices is created which can further destabilise the regime (see also Grin e.a. 2011).

Switzer e.a. (2013) address the criticism of the MLP that there is not enough attention for agency by the development of the notion that practices both are influenced and influence rules, discourses and artefacts (Giddens, 1984; Meadowcroft, 2007; Shove & Walker, 2007; Smith e.a., 2005). Competent actors operate within the constraints of existing structures, but can actively and reflexively seize developments at one level and connect them to change at another level, thus bringing about mutual reinforcement between dynamics at the different levels (Grin, 2006, 2010:274-275; Smith, 2007). An example is the demand for change in the travel patterns of a regime as a result of a growing environmental awareness at the landscape level.

Geels & Schot (2010) propose a model of how structures change and develop as the result of the actions of various actors This is based on the work of Barley & Tolbert (1997) (see Figure 2). When a competent actor undertakes action he draws on this structure (step (1) in figure 2). This supports certain actions and works to prevent others. In this process actors can interpret structure creatively, act counter to them or abide by them (step (2) in figure 2). These actions are the result of interaction with the environment including other actors (in a regime or novelty) or the landscape and expectations about future developments. Based on this experience, structure can be reproduced or changed (step (3) in figure 2). The exertion of power by vested interests (actors) or landscape pressure can suppress change, while landscape developments or novelties can create chances to realise change. Expanding on Geels & Schot (2010), who only considered rules, we define the five types of structure as follows :

- Discourses: An ensemble of ideas, concepts, and categories through which meaning is given to social and physical phenomena, and which is produced and reproduced through an identifiable set of practices (Hajer, 2005). In addition the actions of an actor as well as his identity are part of a discourse (Fairclough, 2003);

- Normative rules: tasks, obligations, responsibilities as well as behavioural rules and societal roles (e.g. social and organisational capital; vested interests, lifestyles and financial incentives and punishments) (adapted from Geels & Schot, 2010);

- Cognitive rules: belief systems, problem agendas and search heuristics that determine which solutions are sought. These cognitive routines are taken for granted and are used unconsciously (adapted from Geels & Schot, 2010);

- Regulative rules: laws and regulations, contracts with formal sanctions for non-compliance (adapted from Geels & Schot, 2010).

- Artefacts: the physical components of the mobility systems (transport networks, patterns of land use)

Finally, in a small number of cases structure can change for good (step 4 in figure 3).

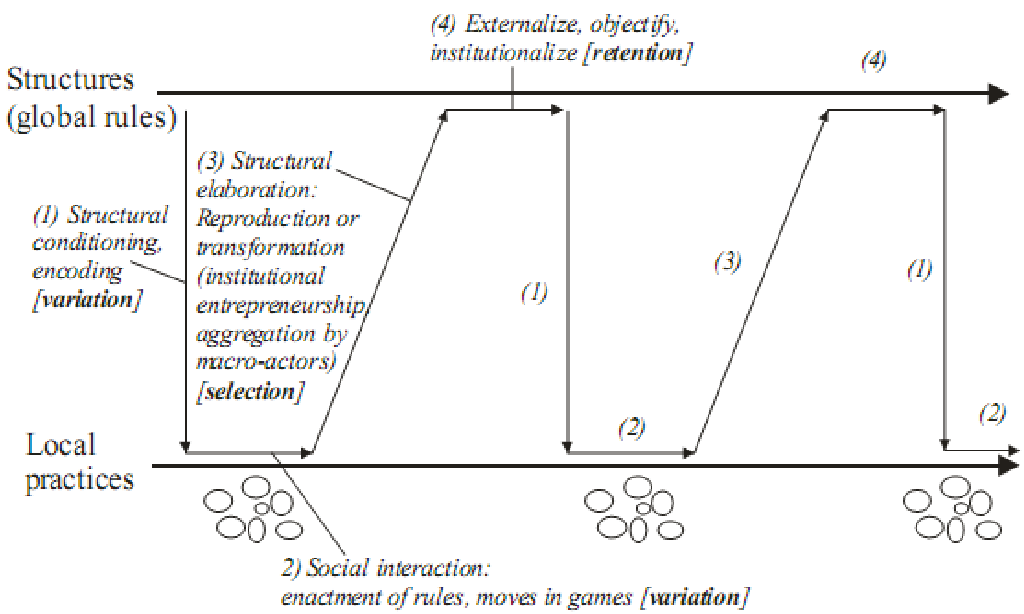

Figure 2 – The interaction between structure and practices (Geels & Schot, 2010) based on Barley & Tolbert (1997)

The intertwined nature of the forms of structure means that changes in a rule, artefact or discourse (taking on a new procedure or applying a new search heuristic or adding bike paths or changing the discourse regarding urban growth) can be hindered by the various forms of structure. The rise of a new discourse can lead to changes in ways of thinking, what is considered a problem and the type of solutions that are considered appropriate (Hajer, 1989). In discourse of environmental protection this can for instance mean that the car that was considered before a symbol of progress whose use should be supported is now seen as a symbol for irreversible damage to the natural environment and a problem for which the logical solution the limitation of use is. The result of this could be that the other forms of structural change as well so that the structural elements are aligned or, on the contrary, that the changes are undone. In the case of a regulative rule this can mean reversing a procedure (e.g. from requiring a minimum to requiring a maximum of parking spaces) , in the case of a cognitive rule, no longer considering a certain type of solution (e.g. building new roads to ease traffic congestion). In the same sense artefacts can hinder the change in rules (as with respect to the examples above this could be the case with low-density, functionally separated land use patterns) or conversely create opportunities that facilitate change (as with dense and mixed historical urban fabrics). Novel practices may then help generate and legitimate discursive changes (Grin & Loeber, 2007), that promote further structural change – and so on.

3. Methodology

To answer the research question of why and how mobility transitions take place a multiple embedded case study has been selected. A transition is defined as follows:

A transition is a social change in a socio-technical system composed of intertwined and self-supporting subsystems for the regulating of a societal function as the result of an accumulation of innovations in its constituent sub-systems caused by interaction and co-evolution between the regime, novelties and the landscape.

3.1 Cases

With the aim of developing hypothesis about how and why transitions take place a multiple embedded case study (Yin, 2009:59) has been selected. The units of analyse are the transitions in the mobility system of Munich since 1945. Munich is the third city of Germany and the centre of a polycentric region. By examining the practices of firms and households (Graphic 1) three periods of transition can be distinguished. Based on secondary sources (Cervero, 1998; Schmucki, 2001) there are additional indications that a transition took place in the period directly after the war and again in the course of the 1970s and 80s. Based on changing practices a possible third transition can be seen as now taking place. Of course, transitions are no clear-cut development, and the dates mentioned below should be seen as indicative. The selection of a period of 65 years was made for methodological and practical reasons The analysis of multiple transitions is expected to boost the explanatory power of the findings (Yin, 2009:59). Practically, primary sources (minutes of meetings of the Stadtrat, various commissions within the city government, newspaper articles, plans, correspondence and regulations and laws) , interview partners who have witnessed and participated in the events since the 1970s and secondary studies from historians and planning researchers are abundantly available for this period. The first step in the analyse was the study of secondary analysis of the planning history of Munich and interviews with experts in this area. Based on this primary sources that provide insight in discourses and rules as well as the development thereof have were consulted.

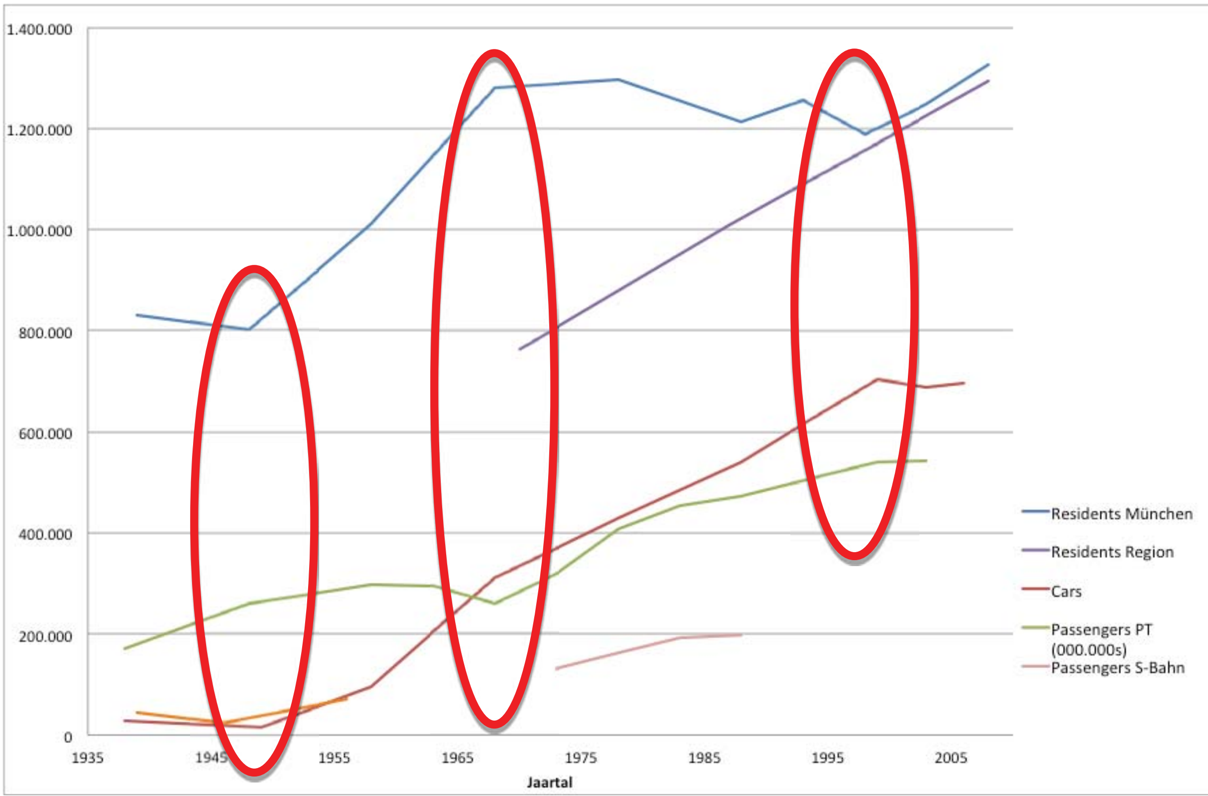

Figure 1: Changes in practices of firms and households (LH München, 1963, 2002,2003,2004,2007; Schmucki, 2001; Linder, 1973; MVV, 2010; Bayerisches Landesamt für Statistik und Datenverarbeitung, 2005; Planungsverband Äußerer Wirtschaftsraum München 2003,2012)

3.2 Method of analysis

In the analysis we consider first qualitative changes (or changes of direction) of the mobility practices of households and firms in Munich and the region as documents by data on location and travel choices (see figure 1). The observed change and the underlying dynamics, found by triangulating the information from documents, interviews and archives will be discussed. Based on the recognition that structural change is the result of pressure on practices (Geels & Schot, 2010) and the resulting debate and conflict we focus in particular on ‘troubles’ as defined by Wright Mills (1959: ff): difficulties encountered by people in their day-to-day practices, partly as a consequence of contested attempts to deal with the issues of their time. In the discussion of the changes in practices and in the analyse we devote considerable attention to landscape changes as well as developments at the national level, that for our purposes is the landscape. Given that these developments were influential for the transitions in Munich they are discussed in various excursions. Table 2 shows how cognitive rules – problem definitions, belief systems and search heuristics – within the regime have changed in the course of time. Attention is devoted to points of departure and four themes that were discussed in most all plans. At the end of each transition analysis the heuristic framework (figure 2) is presented filled in for that transition.

We assess why and how structures have changed, following, and extending, the framework presented in table 1, where changes in the various regime dimension have been phrased in observable terms, for the various processes outlined in figure 2 . To determine if structural change has taken place table 1 will be used. In the case of discourse change, Hall (1993) considers this to be a paradigm change which can be seen as the combination of changes in rules. Hall(1993) describes six phases of paradigm change: stability (institutionalised policy, adaptation by experts and dignitaries), accumulation of anomalies (developments arise that are neither practiced nor explainable through the current policy), experimentation (attempts to stretch existing policy so than new situations can be dealt with), fragmenting of authority (current policy is in discredit, criticism of responsible politic and civil servants, new actors champion change); conflict (debate in the public arena whereby the policy becomes part of a broader political process including elections and party considerations); institutionalisation of the new paradigm (proponents of a new paradigm occupy positions of power and adapt organisations and decision making to anchor the new paradigm)

Table 1: Change in structure (adapted from Geels & Schot, 2010)

Type	Social interaction	Structural elaboration	Externalisation/ institutionalisation	Source
Disc.	Transforming or re-combining incumbent discourse(s) in problem framing or designing and legitimising solutions	Producing novel story lines, metaphors etc.	Discourse institutionalization:	Language used in practices and debates on practices
Norm.	Fulfilling roles, acting according to rules	Small change through negotiation, large change through conflict	Through experience and support of powerful actors	Actions of actors
Cog.	Structure, but freedom for	Bottom up through learning and	Inclusion in hand books, models and	Proposed solutions, plans and policy

	interpretation and creativity	construction of meaning; top-down through macro actors/market selection	manuals	documents (summarised in table 2)
Reg.	Complying with rules, freedom in how strictly this takes place	Lobbying, reaction to negative incentives	Laws and regulation	Change in laws and regulations
Art.	Use of infrastructure and built environment, can be creative	Experimental interventions	Permanent changes in whole city/region	Type and size of infrastructure, use of space

4. Analysis

4.1 Transition 1 (1945-1970)

The first transition started with the interplay between changing practices among households and firms and landscape developments. The municipality of Munich – and later the region – grew quickly, just as car ownership and use. The population growth can be attributed to landscape change including the forced accommodation of refugees from the East and economic restructuring supported by economic growth increased dramatically after the Wahrungsreform of 1948 (see graphic 2). Investments during the war, the relocation of firms from the Soviet Zone and the forced accommodation of refugees contributed to the economic growth (Götschmann, 2013). Employment increased in Munich with 140.000 jobs from 1939-61 while the number of people employed in agriculture in Bavaria decreased with 369.000 (LH München 1963:7; Götschmann, 2013). The decline of the pre-war areas resulted in rapid growth of suburbs just as in many West German cities (Harlander, 1998).

Increasing car ownership and use, as well as the stabilisation of public transport use can be seen as the result of increasing prosperity, and cultural, societal and policy developments at the national level (see excursion 2). The most important landscape changes are shown in figure 4. The population growth as well as the way the troubles resulting from it on the one hand, and the way the troubles resulting from increasing car use were addressed in the course of the 1950s and 60s on the other hand, shed light on the further development of car use and ownership including increasing commuting from the region (LH München, 1963:4)

4.1.1 The demolition of the city and growth

The destruction of a large portion of Munich during the Second World War (Burinaek, 2005) created an urgent trouble for the residents of the city as well as the city government, but also created a window of opportunity for the novelty of modern urban form in which rules and actor networks were stabilised (see Excursion 1). Although some novelty actors made extreme proposals to construct a new city at the Starnberger See the city government selected, due to the costs of moving infrastructure (Meitinger, 1946; Schmucki, 2001,) and a certain attachment to the remembered historic residence city of the pre-war period[1], a reconstruction plan that attempted to combine the historic with the modern (see Table 2). The difference in cognitive rules between the plan makers and the proponents of the modernization resulted in criticism from this group (Himen, 1984). Due to a continuity of cognitive rules (suspicion towards socialist solutions; see Newmann, 1984) an Aufbaugesetz (Reconstruction Law) was never passed in Bavaria, something which hindered the implementation of the Meitingerplan (Himen, 1984). Expectations for future growth (LH München, 1963:7) as well as the further development of politics and science at the national level (see Excursion 3 and figure 4) resulted in the further development of cognitive rules in Munich, namely the concentration of businesses in the centre and housing at the edge. Estates at the edge of the city were selected instead of a Trabantenstadt (satellite city) due to the perceived potential to relieve pressure on the central city and possibilities for financial support from the federal government (see Bruder, 2009: 16)

[1] 'Wir müssen unter allen Umständen trachten, die Erscheinungsform und das Bild der Altstadt zu retten…, damit wir ein eignen Jahrzehnten unser liebes München wieder haben wie es war (Meitinger, 1946)

Excursion 1: The modern city planning

Modern city planning can be traced back to attempts of social reformers, engineers and architects in the 19th century to control the decline in hygiene and living conditions as a result of the demographic growth and industrialisation as well as later critical from social movements (Albers, 1996; Zhu, 2007:21,26). According to this group functionalism, efficiency and beauty be and new possibilities in terms of magnitudes as well the role of market and government be explored (Zhu, 2007: 23, 24). After the First World War the technical possibilities as well as the exacerbated housing shortage created favourable conditions for the development of modern urban form (Zhu, 2007:30,32). For social-democratic and liberal leaders that came to power the social ideal (civic democracy, enlightenment and emancipation) as well as the relationship with progress and change (Aufbruch) attractive (Zhu 2007:32,33).

The Congrès International d'Architecture Moderne (CIAM) resulted in an attempt to establish cognitive rules (Schmucki, 1998; Zhu, 2007:34). The Chicago School as well as Taylorism and Fordism in the USA inspired the avant-garde in Europe. Le Courbusier, one of the leaders of the movement was himself inspired by the production methods in the Fiat factory (Zhu, 2007:29). The car was selected as mode of transport to connect the various areas of the city due to its high speeds and modern image and skyscrapers originating from the US was a central element (see Le Courbusier, 1962: 115-131; Zhu, 2007: 39,44). These developments were not undisputed. Conflicts arose as a result of differences of opinion about the relaxation to the middle age city and the emphasis on the social elements (Zhu, 2007:23, 26, 35). After the exile of proponents of modernism during the war they returned from the US where they were able to further develop their ideas (Zhu, 2007:43,44). Alfred Sperr, the minister of munitions and armament embraced modernistic ideas when making his reconstruction plans (Harlander, 1998).

The reconstruction was seen as a chance for modernists, but there were also proponents of a more traditional reconstruction and the existing artefacts hindered the possibility to make a new start (Albers, 1996; Harlander, 1998). The principals of the Charter of Athens were easy to unite with the developments in the area of transport planning, namely the creation of space for the car (Albers 1996; Zhu, 2007:44; eg. Feuchtinger, 1948). As well as the influence that the US could have through exchange the allies were active in the German debate as was the case for the ECA-Siedlungen (Harlander, 1998). The planning model with skyscrapers and the international style as well as the separation of modes was the form of expression of the Wirtschaftswunder. The desire to build great metropolises was a sign of the limitless optimism of the period (Zhu, 2007:44).

4.1.2 New spatial claims

Increasing car use as a result of the interplay between innovations in artefacts (transport networks) changing land-use patterns as well as changing practices of households – resulted in troubles in the early 1950s. After the war it seems that the expectation at the national level, among scientists (see Excursions 1 and 2) as well as in Munich (see Table 2) to be shared that car use would increase and there was a consensus that this potential problem should be solved – just as in the USA – by increasing the space for this still novel mode of transport. Initially it was expected that motorways in the city would not be necessary (Feuchtinger e.a., 1956), but under pressure of Stadträte concerned about the traffic chaos[i] and the activism of the Süddeutsche Zeitung with its Verkehrsparlement[ii] the Stadtrat, under the assumption that limiting car accessibility of the city centre would be detrimental for the city (Zimniok, 1964:31), begun to search for both more radical and more concrete solutions (Münchner Stadtrat, 1954; Fischer, 1955; Högg, 1958). These cognitive rules were compatible with a discourse of modernity characterised by the authority of scientists and the belief in measures supported by neutral knowledge could ultimately solve problems (environmental and social). The process by which cognitive rules were selected through debate was supplemented by selection from the top down by experts who begun to play an increasingly important role (normative rule)[iii] which was related to a blind trust in them[iv]. Parallel with the rise of Stadtentwicklungsplanung at the national level (see Excursion 3) as a result of debate and the failure of earlier planning attempts the decision was taken to seek solutions in the form of a Stadtentwicklungsplan (STEP) (Lübbecke, 1956) and was the normative role of experts further anchored by giving them the task of making the STEP[v]. The STEP of 1963 symbolises the externalisation and institutionalization of the changed rules after a process of changed intertwined with the development of new practices.

In light of the troubles as a result of new spatial demands the City of Munich sought solutions in public transport in addition to road construction. After the war due to practical reasons (demand) and the image of Munich as a world city investments were made in the tram at a time when many German cities were abolishing their tram networks[vi]. After critical consideration of the situation in the USA, something not unusual in Germany (see Excursion 3), Mayor Vogel, just as other transportation experts argued that public transport was necessary to alleviate the trouble of increasing spatial demands. Just as earlier was the case (MNN 9.11.1905; MNN 23.5.1938) plans were developed for north-south and east-west connections. Both the municipality of Munich and the Deutsche Bundesbahn (DB) were interested in the east-west line between the Haupt- and Ostbahnhof (see Figure 3) (Linder, 1973:40). Attempts to resolve this so-called Strassenstreit (route conflict) illustrate the important role that transportation experts played. They were asked by the Federal and Länder and municipal governments to research alternatives[vii]. Without the participation by higher governments the municipality would not be able to carry out either project. The stalemate that resulted from this conflict (Linder, 1973:44,45, 48; Münchner Stadtrat, 1959b) was only resolved by pressure from other parties on the municipality. The first breakthrough resulted in a change in search heuristics at the municipality where by the connection of Munich to the region through the S-Bahn of the DB was supposed to be beneficial in terms of housing space (Linder, 1973:102,103 ;DB 1960; Bayrischer Staatsminister für Wirtschaft und Verkehr, 1961). A similar situation was present around choice of a U-Bahn (metro) instead of the previously planned U-Straßenbahn (underground tram) and the selection of north-south route instead of the route parallel to the S-Bahn (MStAnz. 31.1.1964, 5:3,4.; Vogel, 1968; Linder, 1973: 106,107)

Excursion 2: The rise of the car

The parallel processes resulting to the subsidence of resistance to the car and those resulting in it being a desirable and unmissable part of a modern life contributed to the increase in car ownership and use in Munich as well as in the rest of West Germany after the war. In the early 1920s the resistance to the car primarily in rural areas was exceptionally hard and sometimes violent (Merki, 2002:178). Merki (2002:193) notes that the difference with France can be attributed to hostility towards large cities and modernity in thinking in Germany connected to the romantic idea of the depth of Culture compared to a supposedly superficial west. For three reasons the resistance towards the car decreased in the course of the 1920s: people and horses got used to the car – partially assisted by technical measures (Merki, 2002); changing structure (laws and regulations) and practise (pedestrians and motorists) by the actions of interest groups and governments (Hölzinger, 2002) and an increase in the economic importance of the car industry (Schmuck, 1996:66; Merki,2002: 194-196, 320-324, 351,363,379; Hölzinger, 2002:84).

At the same time interest groups such as the predecessors of the ADAC and the Verein deutscher Motorfahrzeug-industrieller were active to make petrol more affordable (1907). To support tourism per car, to solve legal issues and to organise motor shows (Merki,2002220-228). The käiserliche Haus was favourable to the car as well as civil servants (Hölzinger, 2002:68). There were also interest groups involved in improving road construction (Hölzinger, 2002:86; Merki,2002: 243). Noteworthy project was the society Autostraße Hansestädte – Frankfurt a.M. – Basel (Hafraba) established to show the usefulness of the car by constructing a motorway (Seely, 1998; Hölzinger, 2002:86). The realisation dawned on those who visited the US that the car was the solution for traffic problems (Hölzinger, 2002:69). In pre-war Germany Amerikanismus or Amerikaniserung were considered synonyms for modern and the influence of the US was visible in various areas (Lüdtke e.a., 1996). Despite this there were also those who were critical of the cultural influences of the US as well as in attempts to learn from the US (Lüdtke e.a., 1996; von Saldern, 1996). After the war developments such as price decreases and the improvement of car and road constructions contributed to the attractiveness of the car (Schildt, 1997).

In both the case of the S-Bahn as the financing of underground public transport as a whole the agency of local actors, and especially those in Munich determining for the change of regime rules at the national level. In contrast to road construction where funding was available for local projects public transport projects were subject to lengthy negotiations (Hielscher, 1961; LH München, 1961). The activism in the case of the S-Bahn on initiative of Mayor Vogel (pressure on members of the CSU governing fraction in the Bundestag) and economic arguments of the Industrie- und Handelskamer resulted in a change in rules whereby in the unique case of Munich public transport was considered a problem for the Federal Government (cognitive rule) and it saw a role for itself in solving it (normative rule)[viii]. The federal government agreed to carry 2/3 of the costs. In addition the earmarking of the proceeds of the purchase of the Lindwurmtunnel by the municipality and an increase of the contribution of the Land Bavaria were important (2.7.64 SZ).

Tabel 2: Contents of various plans

Plan	Point of departure	T&LU	Functions	Centre	Edge	Transport	Housing
Meitinger	- Destruction city, modernisation - Car		-	- Reconstruction in the spirit of the historical centre - Arcades for road widening, no buildings in courtyards	- Modernisation outside of centre	- Altstadtring, U-Bahn in the future - Adaptation to car where possible	-
STEP '63	- Continued growth, München as world city - Historic city is of exceptional value[1] - Vitality and spatial quality of whole city of importance - Traffic management not sufficient for efficiency, good climate for firms, parking places, prevention of congestion	Integral	-Separation	- Political, economic and cultural centre - Vitality outside of office times through metropolitan functions and pedestrian area - expansion	- Radical changes around central city (not sanering, but governance) - Housing in high densities surround public transport - Vital centre around PT-stop	- Road expansion (rings) - Space for car in edge neighbourhoods, limits within Mittler Ring - PT where densities are high - Underground PT needed in centre - Increase number parking places, but maxima	-
STEP '75	- Eternal prosperity history, improvement of quality, balance - München is attractive (housing in central city, no slums, balance housing/employment – this has to be maintained - Reduction of pressure (rent increased, environment, living environment) is objective - Expected intensification in the centre can result in traffic congestion	Integral	- Separation results in loss of quality	- Growth resulted in over dominance of government and consumption in centre and loss of originality and identity - Polycentric city - Retention and recovery of historic urban design has priority[2]	- Housing construction in adjacent municipalities by the municipality München has to be stopped	- Reduction of traffic for liveability and originality - Must support polycentricty - PT as means to reduce danger from cars - Tangential PT & P&R - Increase in attractiveness PT will lead to reduction auto in future - PT connections to developments outside of centre -	- Differentiation supply, social housing has priority - Sanering is necessary -
STEP '83	- STEP '75 is out-dated - München attractive for one person households, decreasing housing production/price increases in historic buildings - Density is high, selectivity is needed when considering functions - Intertwined with region - Take account of green spaces - PT central but car unmissable	integral		- Developments support role as specialised centre of region - Supports subcentres	- No satellite cities (too costly) - New development only i fit does not damage ecological living environments	- PT expansion central - Priority U-bahn - Priority PT inside Mittler Ring, outside car where PT not possible - Coordination PT and car - Expansion of roads only in isolated cases - Pedestrian and bicycle network need to be expanded - Protection from exhaust	- More construction and more affordable housing - Sanering of housing in centre - Support housing ownership - Balanced social structure - Coordination with region -
PM 1998	- Employment and economic prosperity to be secured and supported - Protection of green areas - Environment central -	Integral	Mixing through new zones	-	- Compact urbanity - Densification	- Cooperation with region important - PT supporting densification - PT as way to reduce socially and economically damaging traffic - Expansion of road network only where needed	- Cooperation with region - Densificaion - Priority in centrum

[1] 'Es [München] ist eine organisch geschlossene Gemeinschaft, in der sich die Menschen geborgen fühlen; ein Ort, an dem sie nicht nach Maßlosem streben, sondern die Mitte halten und ein weinig froher, ein weinig glücklicher und erfüllter zu leben glauben als anderswo' (Landeshauptstadt München, 1963:3). Later staat dat zelfs de oorlog dit heeft niet kunnen vernietigen.

[2] Acccording to Maute (1994:142 citeert Landeshauptstadt München 1975 2:11) 'wurde das vordringlichste Ziwel aller Bemühungen darauf ausgerichtet „das allgemeine Bewußtsein zu wecken, daß Gestalt und Originilität Münchens nicht nur kulturhistorisceh Bedeutung für Liebhaber und Touristen haben , sondern Werte darstelle, auf die im Interesse der Lebensqualität, für alle Bürger und das Überleben der Stadt schlechthin nicht verzichtet werden kann

At the same time the Städtelobby established on the initiative of Mayor Vogel exerted pressure on members of the Bundestag and carried out actions such as the Fligende Pressekonferenz (Flying press conference) to attract attention to the traffic problems in cities[ix], which resulted in a change regulative rules and research that would increase policy attention for the needs of people in addition to motorists and the health of cities[x]. Public transport projects could be financed through petrol taxes from 1966 (Bundesminister für Verkehr, 1964 and the Gesetz über Finanzhilfen des Bundes zur Verbesserung der Verkehrsverhältnisse der Gemeinden or the Gemeindeverkehrsfinanzierungsgesetz (GVFG) was passed. The arrival of a progressive SDP minister of transport is both a sign of the change and a factor that accelerated it.

On 1 February 1965 the construction of the U-Bahn was commenced and on 15 June 1966 the works for the S-Bahn were started. The U-Bahn was the responsibility of a separate department (U-Bahnamt) was the first project financed by the Federal Government (Der Stadtverkehr, 1966). The project was accelerated from 1967 by the awarding of the Olympic Games[xi].

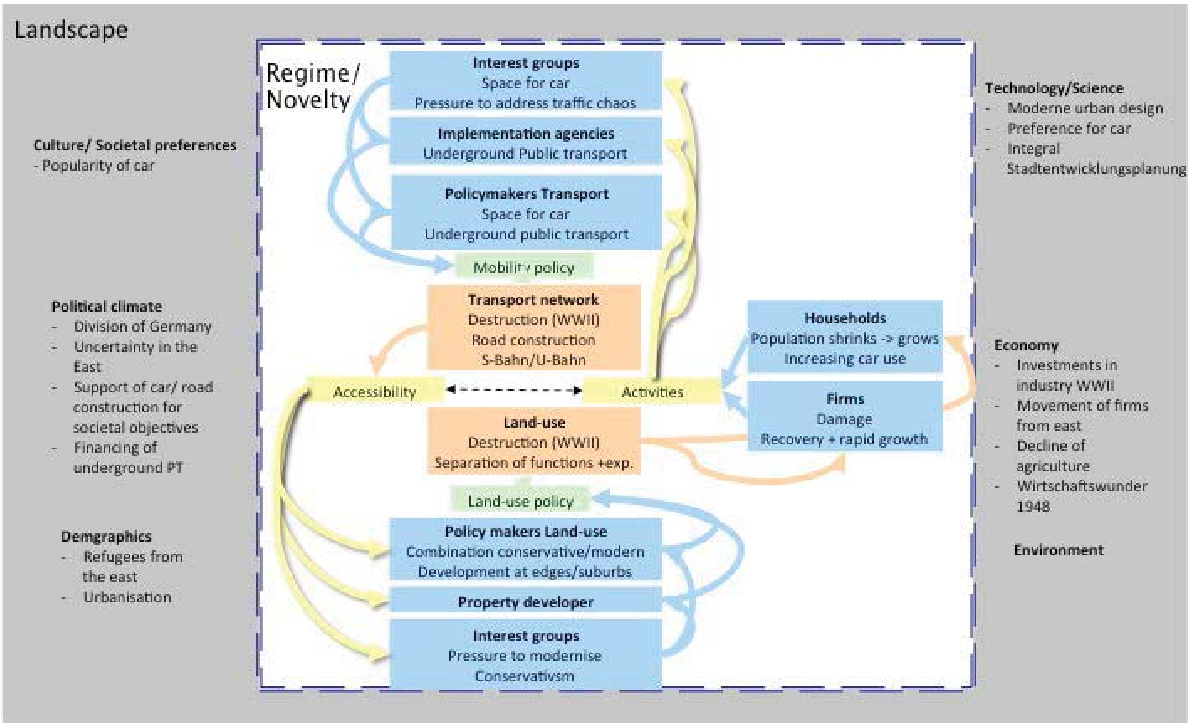

Figure 2: The development of the mobility system during the first transition

Excursion 3: Policy developments at the national level

The car as symbol of modernity, prosperity and the free was was associated wit the reinvention with the German identity in contract to the NS past and the communistic east. For Klenke (1995:37) the car better satisfied the need for freedom, personal expression and unstructured self-responsibility that was necessary as a result of the modern lifestyles in an industrial society characterised by untransparent division of labour. In addition, after years of hardship and forced seclusion American values were seen as the same as world openness, progress and modernity (Klenke, 1995:40; Schmucki, 1998). Hopes were projected on the US and the treatment of Germans contributed to this (Lüdtke e.a., 1996). The enthusiasm for the car and motorisation was also visible in media reports (Schildt, 1997). Klenke (1995:36) describes how the car was seen to have a social integrative function. The idea behind the post-war role of the car was that it would lead to blurring and disappearance of class differences and spread satisfaction and happiness as stated by Verkehrsminister Seeborm in 1958 (Klenke, 1995). This would also hinder extreme communal ideals and an instable political climate that was caused by large groups of receptive people as before the war. The car was supported from the mid 1950's onwards by the reparation and expansion of motorways, the deductibility of commuting travel, the Straßenbaufinanzierungsgesetz (earmarking taxes for road construction), the Gemeindepfenning for road construction in municipalities (Klenke, 1995:35,63). The VöV foresaw the necessity to adapt public transport to the car (Schmucki, 1998; Schmucki, 2001: 95).

Prior to the war the US was influential in the development of concepts for transport planning (see Neumann en Feuchtigner, 1937) and in the period following the interaction was more intense. For Americans infrastructural investments were interesting as they would lead to stability and because Europe was a growing market (Liebbrand, 1957; Feuchtinger, 1957; Seely, 1998). Educational programs were set up by the Americans (Schmucki, 1998). The U-Bahn was embraced while the tram was seen as out-dated (Schmucki, 2001:104). In articles the city was considered an organism and there was awareness that public transport was necessary to avoid American conditions (see Feuchtinger 1948 and König 1948)

The decision to build the motorways can be seen as the start of the decline of the railroads. The Reichsbahn was given the task of building these roads as a way to prevent resistance (Hölzinger, 2002:95, 98).. Competition, economic change, the costs of the reconstruction and financial requirements resulted in a precarious situation for the DB after the war (Schmuck, 1996:40, 41). In the course of the 1960s pressure increased to abandon unprofitable routes (Linder, 1973:119; Hölzinger, 2002:148)

At the end of the 1950s as a result of economic developments and changes in politics and government it became evident that societal and economic planning were necessary elements of a spatial plan (Albers, 1996; BMWBS & BBSR, 2009). Stadtentwicklungsplanung was the result in Germany. Despite the adoption of the Bundesbaugesetz of 1960 the role of the Bund was limited (Albers, 1996). This was also the case in the Länder such as Bavaria. In the 1960s the attention was moved from the reconstruction to the development of the city centres to central business districts (Harlander, 1998). At the same time increasingly more large estates with social housing were built. According to Harlander (1998) the objectives were changed from a city landscape and a structured and spatially relaxed city to simply accommodating growth.

4.2 Transition 2 (1970-1995)

From the end of the 1960s onward a turning point in the practices of households is visible: car ownership increased more slowly and public transport use begun to increase as the population of Munich stabilised and the region grew more quickly (see Graphic 1). For many households a house in a suburb was seen as a chance to escape from the polluted and depraved central city (Linder, 1973:188) while increasing property values, especially for families increased (Lidner, 1973: 185, 188). The policy of the municipality played a role in these changing practices in terms of road construction and the preference for offices before housing in the central city. The economic development and the growth of the service sector in Munich and environs (Kohlmaier, 2007) meant that the pressure from property developers was present to construct. The increase in public transport use can be seen as a result of the interplay of interventions in artifacts (transition 1), the locational choices of households and the modal choices in light of decreasing car accessibility in the central city (see Figure 6).

The second transition was the result of a collision between discourses and rules of novelty and regime actors. The interventions that were envisioned in the STEP ’63 (Table 2) were criticized by architecture students and citizens as well as the Münchner Bauforum (later Forum) – an important novel organisation – as too radical interventions in the historic fabric (this was qualified as destruction and the loss of character/originality) and nature areas for which other alternatives should have been considered[xii]. This was also the case in other German cities (see Excursion 4) and is related to an increase in criticism in a variety of areas (see Figure 5). In the rising discourse of livability new problems were visible (environment and the loss of character) and the role of experts (no longer in possession of absolute knowledge) was redefined whereby new solutions were seen as possible. The condition for solutions was just as was the case in the regime the protection of the city. However the fundamental assumption of a predictable and makeable future based on 100 percent reliable prognoses was replaced by a belief that these were valuable to the extent that they contributed to the exploration of possibilities (Wallenborn, 1967).

Initially, the regime reacted defensively (see Klühspies, 2009), normative and cognitive rules but with the promise of open planning and the integration of the Münchner Forum in the planning apparatus these rules were changed quickly (Wallenborn, 1967; Luther, 1968). It is plausible that the criticism of young members of the SPD (party of Vogel) about the loss of originality (Schmucki, 2001:345) as well as the intensity of protests that were compared to the riots that had early plagued the city and similar novelties elsewhere contributed to the speed of change. A the same moment the foundation of the worldview of the regime evaporated with the economic crisis and the report of the Club of Rome that made abundantly clear that neither that the future was predictable nor that the technical remedies could solve all problems of modernity could be assumed (see Excursion 4).

In preparation of the STEP of 1974/75 the reactions were largely negative towards investments in car infrastructure[xiii]. The changed objectives (see Table 2) as well as the comments of Mayor Kronawitterthat in light of the economic crisis and the decrease of population Munich should become ‘kein Manhattan aber auch kein Museum’ (SZ 24.6.1975,141:17). At the Planungsamt novel practices were accepted among the many new employees more quickly than by other departments (U-Bahnreferat, Tiefbauamt en Stadt kämmerlei) where there was resistance (Schmucki 2001:345; SPD München 1975; Schmucki, 2006). Controversial plans such as the Isarparalelle and the demolition of the Viktualienmarkt were no longer included in the STEP 1974/75[xiv] but the demotion of historic buildings to create room for the European Patent Office still took place and public transport did not receive priority in traffic. In the second half of the 1970s protests from citizen groups continued (Aktion Maxvorstadt, exhibition Erholungsraum Stadt- Leben mit der Straße) and architects (eg. Schleich, 1978) for which there was attention in the media (MStAz 15.6.1978). In cooperation these protesters were able to gain the attention of planners (Eichenauer e.a. 1978). Only in the STEP of 1983 was it apparent that cognitive rules had changed for good (Schmucki, 2001:367) (see Table 2), something also supported by the conservative CSU. Further support for the change is the rescaling of the crossing in the Altstatring, tempo 30 and reduced traffic areas and the support for biking[xv]. At the end of the 1980s research confirmed that the public opinion was negative towards the car (Socialdata, 1989).

The change of discourse on the spatial side took place quite quickly although there are doubts about the extent in which these were shared by all parties. In terms of public transport planning practices remained unchanged. From the 1960s onwards cognitive (starting with construction before financing was secured) and regulative rules (financing from the federal government of up to 80 percent) were so securely anchored that a certain momentum was present in the U-bahn planning (Hass-Klau, 1984). Schmukci (2001:328) mentions a U-Bahnparadigma where many departments were supportive of the U-Bahn constructions and it seemed as if all interest groups and parties supported the construction (Kurzprotokoll über die Besprechung i.S Ausnutzung der Nord-Süd-U-Bahn im Abschnitt v… 2.8.1967 StAM RSP 740/17,Zimniok, 1981:159). The plan to fully replace the tram with busses and the U-Bahn was reason for the initiative ‘Rettet die Trambahn’ supported by activists (Münnchenr Forum and Aktion Attraktiver Nahverkehr) and Stadträte from the SPD and FDP[xvi]. In this case a collision on rules is also visible between supporters of the tram as part of human and livable city (Frenz, 1979) and the public transport company for whom the tram was a question of technological modernisation[xvii]. The resistance of (organized) citizens increased the pressure on the public transport company[xviii].

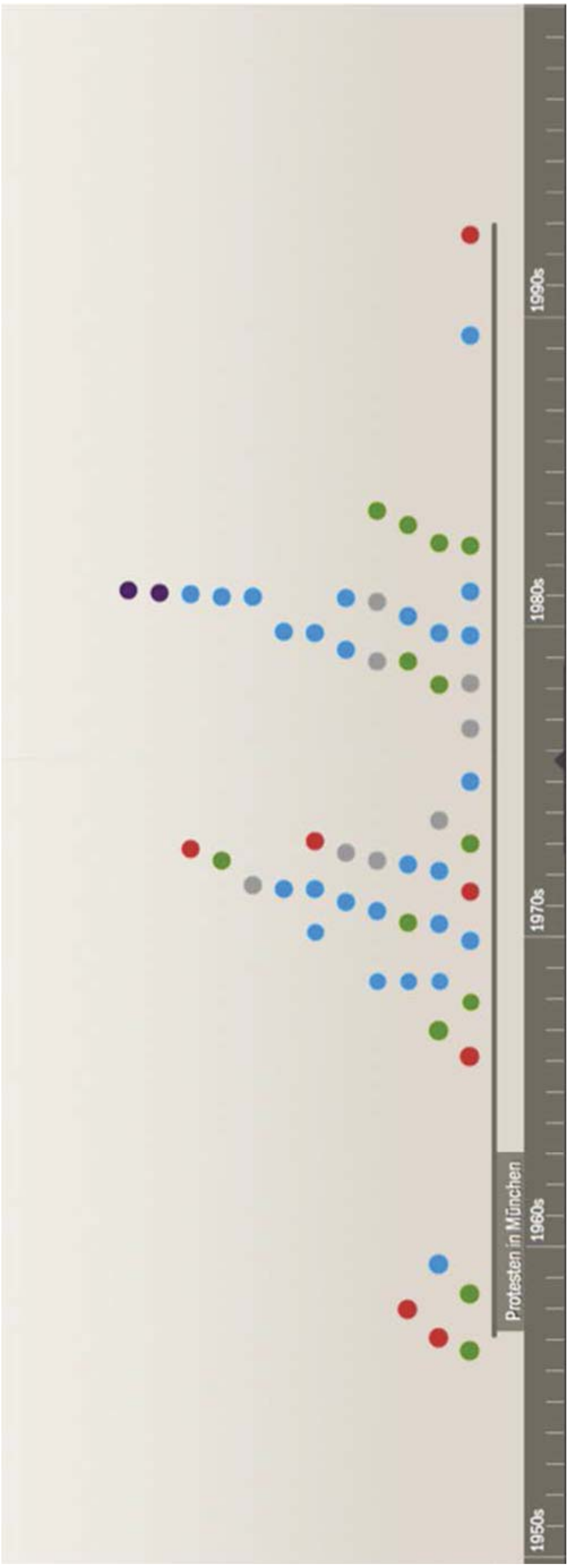

Figure 3: Protests in Munich

First the decision on the plan (öV-Konzept2000) was postponed[xix] and in 1984 SDP'er Kronawitter defeated the reigning mayor Kiesel (CSU) with the motto 'so viel Trambahn wie möglich'[xx]. At the same time a report was published that advised the expansion of the tram (SZ 7.2.1984 31:9, SZ 7.12.1985). What the tram is concerned in 1988 the purchase of new rolling stock was approved and supported by the Bund in keeping with changes there (see excursion 4). In 1990 the first integral public transport plan that considered all modes was adopted (SZ 6.7.1988, 153:13; SZ14.12.90 287:21; see also Kesselring, 2001:28; 113).

Excursion 4: Democratisation in the 1960s

From the mid-1960s onwards protests broke out in a number of areas against the current situation: the role of women in society, civil rights or the planning of the city. Citizens who were able in the previous 20 years to guarantee the basic necessities started to be more concerned with immaterial things and criticised the claim of officials to be best able to make decisions. Troubles that existed previously were redefined. The focus of the young generation was broader than the reconstruction and moralistic objectives such as participation in public life, democracy, environmental protection and equality were central themes (Zhu, 2007:47). What the planning of the mobility system is concerned the redevelopment of the central city and the car were subject of discussion. Criticism of the scale of developments, restructuring and the relaxation of the city, which resulted in the loss of urbanity (diversity and intensity) increased. This is also present in other countries and visible in professional literature (Albers, 1996; Cullen, 1961; Siedler e.a. 1964). In the 1970s planning was embroiled in a crisis due to problems with the environment, energy and employment (Haefeli, 2006:62; Gnest, 2008). Spatial planning could not deliver what was expected in the 160s (Albers,1996, Gnest, 2008) and there were many protests in German cities regarding the historic centres and the needs of citizens (Albers, 1996;) As a reaction to this the Städtebauförderungsgesetz of 1971 and the Bundesbaugesetz of 1976 – organising participation – were approved.

In the early 1970s the awareness of the environmental impacts of the western lifestyles increased. The report of the Club of Rome and a UN conference about the environment took place in 1972 (Klenke, 1995:84-85). The disadvantages of the car were apparent (also in terms of traffic deaths) and the economic crisis made it clear how dependent the German economy was on the car sector (Bratzel, 1999:207; Haefeli, 2006:65, see also Schröder, 1971; Winter, 1971; Dollinger, 1972; Farenholz,1977:167; Schmucki, 2001:164)). Criticism of the car grew. In the 1980s Waldsterben and smog were major problems (Der Spiegel, 1981; Klenke, 1995:104-105; Haefeli, 2006:67). In terms of policy a report from the Bundestag was published in 1973 dealing with environmental issues (Klenke, 1995:90; see also: Schmucki, 2001:371). Towards the end of the decade the criticism was able to have more influence on policy due to the better organisation of critics (founding of the Grüne Partei) and the ecolisation of the statements of established nature groups (Haefeli, 2006;66). At the same time the awareness of energy issues increased as a result of the car free Sundays (Bratzel, 1999:207). Despite these developments and the investments in regional public transport the investments in roads decreased slowly and focus was on technology (catalytic converters and new modes of transport) while the costs of car ownership and use decreased, the commuter subsidy increased and speed limits were rejected (Klenke, 1995:102,117; Bratzel, 1999: 207-210; Schmucki, 2001:164; Haefeli, 2006:66-67)

In the late 1970s planning became more fragmented and incremental, but also more focused on the environment and influenced by austerity programmes (Gnest, 2008). In this period the ambitions of planning in terms of coordination, the expected influence of planning on social economic developments and the expectations of predictability were adjusted (Albers, 1996; Gnest, 2008).

In the late 1980s conflict and tensions between a strengthened novelty and the old regime were present (Die Zeit, 13.10.89, 42). In the case of a tunnel in the Mittleren Ring the division between the SDP and Grüne (in power in the city) oriented towards livability and the proponents of a more car friendly polity (CSU, ADAC and the Industrie- und Handelskamer) for whom good car accessibility was question of life or death for the city were clear (Schwabing extra. 1.6.96, 1; *Stadtratte* 33; Kesselring, 2001:116). The tunnel was finally approved in a referendum in the city as a whole and in the surrounding areas in 1997 (Wochenanzeiger 10.08.09). An attempt of BMW to propose a Blaue Zone represented a large step in terms of cognitive rules at the company limitations for the car and thinking about livability) but this was rejected by Stadtrat as being still too pro car (Kesselring, 2001:113, 115). Cognitive and normative rules were changed as a result of the realisation by the Grünen that cooperation with an actor that was not involved in the ecology movement could be advantageous and the step of the departing chairman of BMW to invite actors to Inzell to cooperatively search for solutions to transport problems (Kesselring, 2001:85). This resulted in changed search heuristics. The exclusive logics, rationalities and interests of the parties were accepted and compromises were sought. In public the emphasis was placed on what the group had achieved which limited criticism (Kesselring, 2001: 117; BMW &LH München 1998:6; Kesselring, 2001:145). The role of BMW changed from an interest group to a policy maker amongst other ones and communicative planning was central (Kesselring, 2001:145). In light of the developments at the national level this is not surprising (excursion 5). The result in terms of established cognitive rules is visible in the plan Perspektiv München (table 2) with progressive objectives, but where conflicts in implementation are avoided though a lack of clarity (e.g. necessary traffic is not defined) (Kesselring, 2001:139-141)

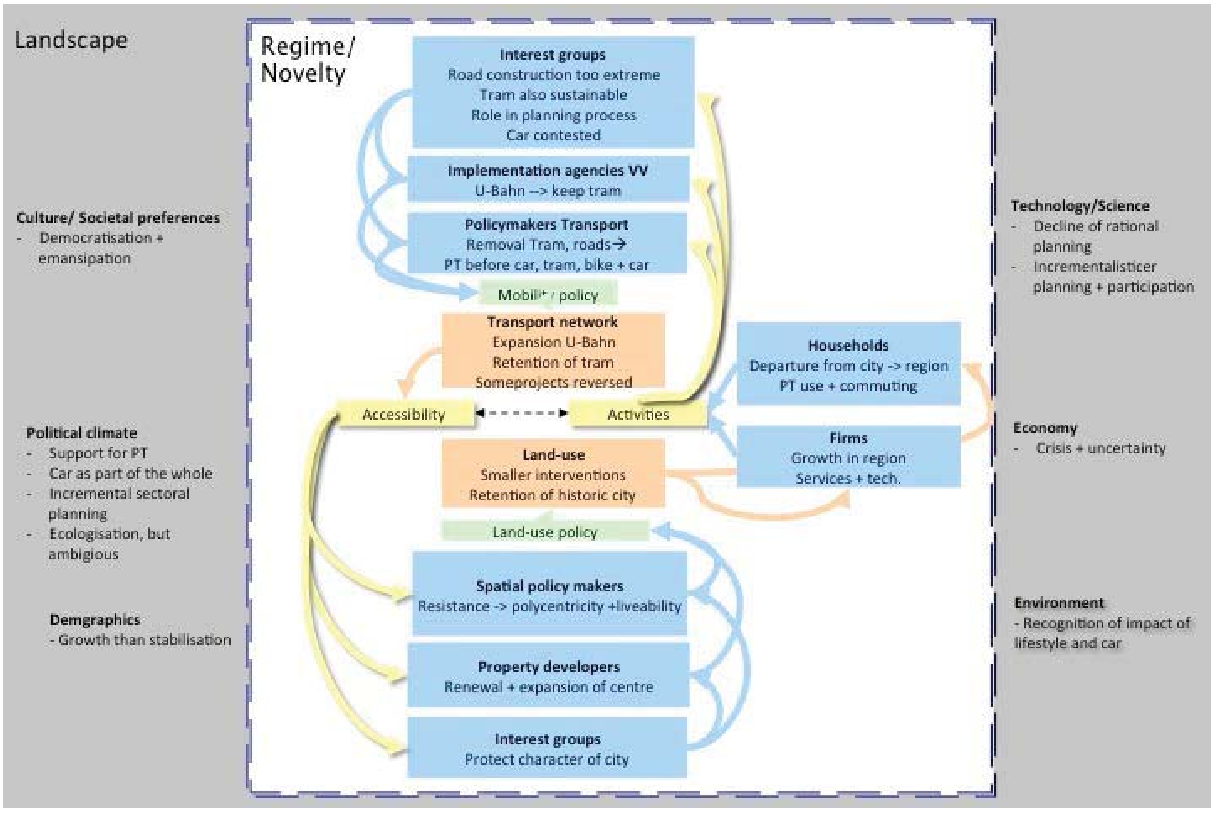

Figure 4: The mobility system in transition 2

4.3 Transition 3 (1995-present)

Since the 1990s there are indications that a third transition may be starting based on changing practices of households and firms. Munich started to grow once again and at the same time the number of cars in the city has decreased and the share of biking has increased considerably (17 per cent in 2011) (Kürbis, 2012; Maute, 1994:165-167). The stabilisation of the number of cars and the rise of biking can be explained by societal developments at the national level (see Excursion 6) but also by the high densities of their city, the monocentricy of the central city and the retention of the structure of the pre-war city. The return to the city is not limited to Munich and is present in many German large cities (see Excursion 6). The high quality of life compared to relatively low costs of living as well as the continued strong growth in high tech and service sectors in the city and surroundings (stronger there than in municipality) have resulted in an exceptional attractiveness (Maute 1994:164-167; Kürbis, 2012).

Excursion 5: Recent developments in planning

In light of globalisation demographic change, spatial fragmentation, environmental problems and financial problems in the 1990s it was increasingly realised that an integral approach was necessary (Ritter, 2006; BMWBS & BBSR (2009). In contract to Stadtentwicklungsplnung the assumption is not a complete rationality and governance at a high level of detail but rather a complex intertwined rationality with related challenges and solutions oriented towards implementation (BMWBS & BBSR, 2009). Attention was increasingly devoted to regional planning with supporting instruments (Regionaler Entwicklungskonzept, Planning conferences and city networks (Gnest, 2008). The importance of spatial planning at the federal level has increased according to Gnest (2008). Indicative is the combination of the Bundesverkehrs- and Bauministerien. With the independence of the DB (Bratzel, 1999: 206; Hölzinger, 2002:164) and decentralisation to the Länder and the municipalities what public transport is concerned (Bratzel, 1999:217) the role of the Bund has become smaller. The complete halt of financial support is foreseen for 2020 unless the Länder and Bund can agree on a replacement for the GVFG. The focus on equal living conditions is no longer a goal of spatial panning. These are now growth and innovation, security of existence and conserving resources and the organisation of cultural landscapes (Gnest, 2008). The premier of Bavaria has promised reduce spatial planning to a minimum and it is now part of the ministry of Economy, transport, infrastructure and technology (Gnest, 2008).

4.3.1 Regionalisation

The growth of the city and the region in economic terms as well as in terms of the locational preferences of firms has resulted in troubles in the city as well as the region. Congestions in the S-Bahn was ground for the MVV to construct a second tunnel under the central city (Brauer, 2009). A conflict arose between actors who defined the problem regionally (Münchner Forum etc) and those more oriented towards the city (SZ 27.01.06; Abendzeitung, 24.03.2010). Finally the project was approved with broad support in both the Stadtrat and the Landestag with support from the Federal Government in late 2012 (Abendzeitung, 24.03.2010; DB & BSMWIVT, 2012).

A further trouble resulting from regionalisation are problems in regional municipalities such as development pressure on green areas, the disproportional distribution of growth with financial consequences and pressure on infrastructure (Reiß-Schmidt, 2003; Pütz, 2006; Habaoui-Engelhard, 2008). New cognitive rules are being developed (see Pütz, 2006; Priebs, 2006) but regulative and normative rules, namely municipal autonomy and the local planning competence as well as an electoral system that emphasises individuals have prevented the creation of stronger regional institutions a change in cognitive rules and practices which could result in a shift of attention to regional issues (Reiß-Schmidt, 2003; Haberer & Mailer, 2005). There is evidence that rules are changing slowly: Forum Stadt und Umland in the Inzell-initative and the cautious recognition from municipalities that more (not compulsory) cooperation is needed in the areas of public transport and Bauleitplanung (Habaoui-Engelhard, 2008). At present the trend at the level of the Land is decreased influence of government on development (Miosga, 2011)

Excursion 6: Mobility and residential preferences

Since the 1990s two trends can be distinguished. Firstly the rise of the bicycle as a legitimate mode of transport. The bicycle share of the modal split increases in many German cities where it is seen as part of culture with a good reputation (SZ 17.04.12; SZ 03.09.12; Infas & DLR, 2010). The bicycle is increasingly seen as a status symbol (BMVBS, 2012:10). Since the year 2000 regulative rules at the national level support biking (SZ 04.09.12, BMVBW, 2002). IN the first Nationalen Radverkehrsplan (NRVP) attempts were made to support biking address legal issues (BMVBW, 2002). It was seen as a healthy, environmental friendly and socially responsible mode of transport (BMVBW, 2002). Due to criticism of a lack of attention for biking and safety issues the second NRVP (BMVBS, 2012) has devoted attention to communication and infrastructural improvements (SZ 10.05.10; Der Spiegel 2011). Incentives and normative rules have been adjusted such as the same support for bicycles as for company cars (SZ 4.12.12). At the same time the availability of cars and possession of drivers licences among youth have decreased and more attention is being devoted to car sharing, which has also drawn the attention of regime actors such as Daimler (BMVBS, 2012:10; SZ 27.12.12; SZ 20.01.13). According to critics there is a generation that consciously has chosen to not purchase a car and uses the Bahncard and car sharing to be mobile (SZ 17.04.12).

Secondly the city has become a desired living environment, primarily for young adults. The same middle classes that left the city have begun to choose it above a suburb. Since the year 2000 some cities have experienced considerable population growth while in other areas shrinkage was on the order. BBSR, 2012)

4.3.2 New spatial demands

In the 1980s and 90s the bicycle was associated with a counter culture and was used in protests against car infrastructure and for public transport (Stadtchronik, Stadtarchiv München; SZ 250, 1). The growth of bicycle use has resulted in increased pressure on the available roadways. Recently here were conflicts between parties (SDP and Grüne) that sought solutions to support the bicycle- sometimes at the cost of the car – and the CSU and FDP who continue to emphasise the importance of car accessibility (SZ, 20.11.11; SZ 14.03.11). Reports of uncertainty with regard to how far measures should go indicate the continue instability of cognitive rules (see SZ 17.04.12). For others these actions do not go far enough (SZ, 20.11.11). Bicycle organisations demonstrate to demand more space (see SZ 17.04.12). With increasing activism further conflicts are possible that could be the beginning of further change in rules, discourses, rules, practices and artefacts.

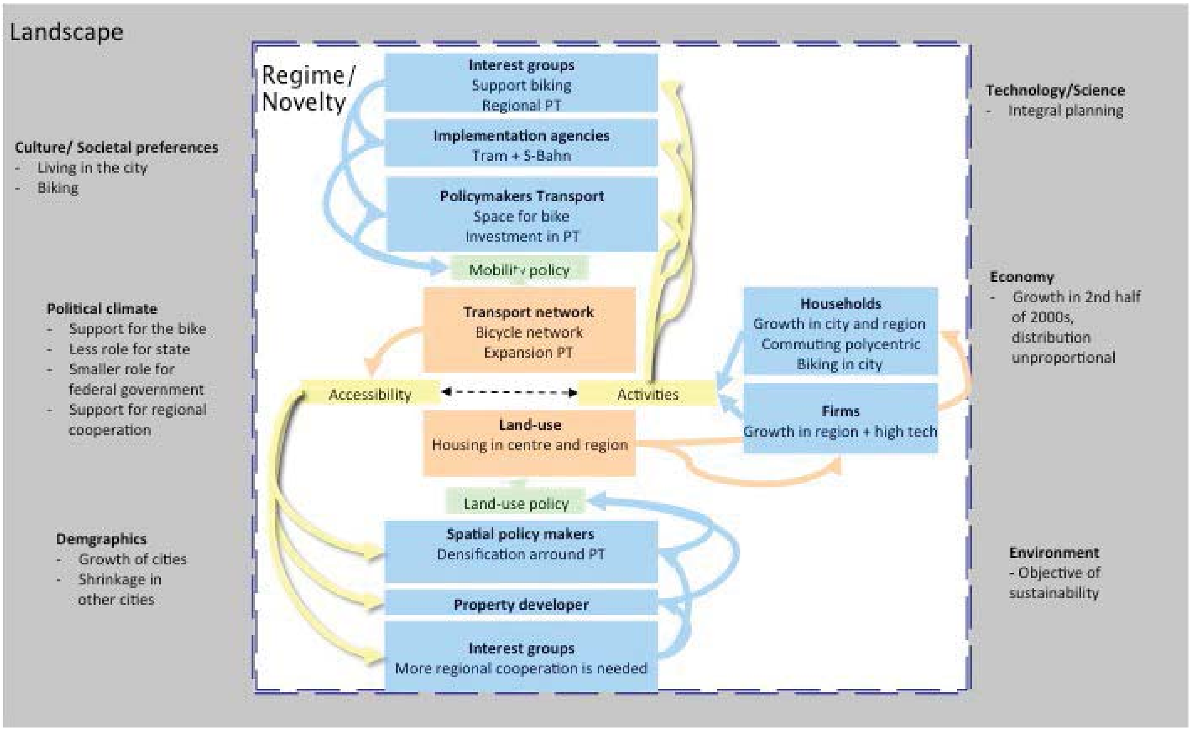

Figure 5: The mobility system in transition 3

5. Conclusions

Below the questions of how and why transitions in the mobility system take place are answered based on the discussion above. Subsequently, four hypotheses ensuing from these answers are presented. As answer to the question 'why do transitions occur' the first transition, from 1945 onwards, shows how a transition can start in the landscape and how this can also create chances for a novelty. Economic (strong growth from 1948 onwards), political (the Second World War, federal support for the car and the division of Germany) landscape developments in the form of an avalanche (see Schot & Geels, 2010) as well as disruptive changes in terms of culture and society (the popularity of the car in the whole of Germany and the discourse of a malleable society whereby problems such as social differences or the rise of radical ideas in gatherings of people could be addressed or prevented through the improvement of living conditions and individuality through the car respectively) and technological (the further development of the car)'landscape' created conditions that favoured increase of car use and supported the novelty. This change in mobility practices of households created pressure on the former regime that was seized by novelty actors who were proponents of a modern urban form and space for the car. For these actors saving the city

– the conservation and defence of identity- was the objective. The rapid change in the landscape created a window of opportunity for the well-developed novelty.

The second transition, around 1970, shows how the reinterpretation of landscape trends can be the start of a transition, but also how these can create chances for change. Novelty actors that were part of a counter discourse considered the interventions in artefacts carried out by regime actors as the second destruction of the historic city. This contrasts sharply with regime actors who considered the change in the identity of the city to be a way of saving the city. It is not surprising that resistance arose at the moment that the regime from the first transition was established. Actors who likely always had different ideas about the identity of the city than regime actors were forced to make their standpoint with regard to cognitive and normative rules more concrete. As such they defined problems differently (loss of identity through extreme interventions and the loss of a liveable city), they sought other solutions (smaller interventions, solutions that placed people at the focus of planning) and emphasised other normative roles (more space for citizens and less direct influence for experts. The window of opportunity was opened by shocks in the landscape (recognition of environmental damage, the economic crisis) and disruptive change (similar criticism in German and abroad about the development of cities that grew in the years previous). These changes delegitimised beliefs and assumptions that formed the foundation of the discourse and cognitive rules of the regime and changed power structures.

The third transition, around 2000, is similar to the first. Disruptive landscape developments the rise of biking and urban living (culture and society) and the receptiveness for arguments of sustainability due as a result of the second transition (political climate) have resulted in a change in the practices of households, which has placed the regime in Munich under pressure. In addition developments that have been present for quite some time, namely regionalisation, have increased pressure on the regime. Based on the earlier transitions it can be expected that further development of novelties supported by the landscape as well as possible shocks or avalanche changes could result in conflicts with the regime from the second transition.

In answer to the questions of how transitions occur it was of importance, in the first transition, that interest groups (newspapers, citizens, scientists and progressive members of the Stadtrat) insisted that what they considered traffic chaos be addressed. Just as important was the broad consensus about what the problem was and how this should be addressed – cognitive rules – a sign of a well-developed novelty. The typically modern ‘malleable society’ discourse (this legitimated the role of experts and the search heuristics) as well as developments in science (the rise of Stadtentwicklungsplanung and the insights of traffic engineers) and political climate that coincided with attempts to with the attempt to develop policy namely the structural elaboration and internalisation of normative and cognitive rules. When considering the change in policy in the landscape (political climate) to support underground public transport the making of collations between interest groups, policy makers and other actors (members of the Bundestag and mayors of other cities) essential.

The second transition shows how a novelty that begins with protest from activist interest groups can result in transition. These were actors who casted doubts about what policy makers, implementation agencies and property developers as well as other interest groups were doing. Citizens supported these protests, which was associated to a broader societal trend of democratisation from which legitimacy was derived. Together with the debate at the national/international level, this promoted the rapid change of cognitive rules, among some actors; especially those whose position was destabilised. These actors were forced to cooperate with actors from the novelty as was the case for mayor Vogel. This was not the case among many actors (U-Bahnreferat) and hindered change. In the following period the practices of households and firms changed slowly. The strength (stability of rules, power of actors and legitimacy of practices) of the novelty increased as the increasing support of former opponents shows, but the regime was not replaced as certain interventions in artefacts show. Finally a compromise was made between the former regime and novelty actors to overcome / transcend disagreement about cognitive rules. A coalition was created, between regime and novelty but it was not one dominant regime if cognitive rules and discourses are considered. However, in terms of normative rules (e.g. role of BMW) or regulative rules this is the case This coalition is stable until today due to the ability to adapt cognitive and regulative rules to what Schot & Geels (2010) describe as regular landscape change and limited pressure from more radical novelty actors where necessary

The third transition is comparable to the firs in the sense that a well-developed novelty is present in terms of cognitive rules among progressive actors. These actors have proven willing to support changing practices of households. This is something which has recently resulted in tensions with actors in the old regime

Hypothesis 1: landscape change can creates chances, but these need to be legitimised by novelty actors - who also derive power from it – in conflict with regime actors to make transition possible

Hypothesis 2: Threats to identity are, in the case of the mobility system, an essential impetus for actions of novelty actors that result in transition.

Hypothesis 3: Changing practices of households and firms (mobility behaviour, locational choices) are a necessity of transition and based on the speed of the first transition it would seem that the pressure resulting from these changes can expedite a transition

Hypothesis 4: Cooperation between actors if voluntary can be a way of brining about transition. If forced upon actors cooperation is also a way to bring about rapid change in rules

These four hypotheses are based on an embedded case study in one case, but given indications that are relevant for policy makers seeking to achieve transition. This research has also shown how a refined version of the heuristic framework of Switzer e.a. (2013) can be useful in structured inquiry in historic transitions. Because these hypotheses are based on one case the robustness is somewhat limited (Yin, 2009:54). To improve this we recommend further research in another context to refine these hypotheses as well as the testing of them in a case where transition has been attempted, but not taken place.

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A literature review on

Energy Innovation Systems

Structure of an emerging scholarly field and its future research directions

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Table of contents

1 Introduction and overview ... 3
2 Energy innovation system research: different perspectives ... 4
2.1 Energy research in the NIS, RIS and SIS perspective ... 5
2.2 Development of the TIS perspective ... 7
2.3 Major lessons from TIS studies on new energy technologies ... 10
2.4 Towards an integrated agenda on "energy innovation systems" ... 11
3 Major challenges in developing the TIS research agenda ... 12
3.1 Core concepts ... 12
a) General ... 12
b) Functions concept revisited ... 12
c) Actors, networks and intermediaries ... 12
d) Concept of Institutions ... 13
e) TIS life-cycle and transitions ... 13
3.2 Methodological issues ... 13
a) Measurement of functions: ... 13
b) System boundary setting ... 14
c) Extending the methodological tool-box ... 14
d) Predictive models and strategic planning ... 14
3.3 Considering contexts more explicitly ... 14
a) Spatial contexts: National, regional, global, multi-scale ... 15
b) Sectoral contexts/regimes ... 15
c) TIS context and TIS – TIS interaction ... 15
3.4 Policy implications ... 15
4 Development trends in the most recent energy EIS literature (2010-2011) ... 17
4.1 Publications in the conceptual core of TIS research ... 17
a) Policy implications / Governance of TIS ... 18
b) Considering contexts more explicitly ... 18
c) Actor strategies ... 19
d) Functional approach to TIS ... 19
e) Extending insights from TIS studies to other literatures ... 20
4.2 The wider scholarly context of energy innovation systems research ... 20
4.3 Triangulating the conceptual core and empirical context of energy TIS research ... 23
4.4 Discussion of most recent trends in energy TIS research ... 26
5 Conclusions and outlook ... 27
6 References ... 29
7 Appendices ... 35
7.1 Appendix A: Publications in the conceptual core of TIS studies ... 35
7.2 Appendix B: Literature list from triangulating empirical core and empirical context of TIS ... 36

1 Introduction and overview

Energy related innovation is receiving increasing attention worldwide. This may be explained by recent developments in the policy discourse in many countries. The threat of global climate change, projections of scarcities of fossil sources (peak oil), and major disasters like Fukushima have put the need to radically rethinking and rebuilding energy sectors very high on the political agenda of many countries. National energy policies in countries like Germany or Switzerland have been formulated to move out of nuclear power and to embark on an energy sector transition that builds on renewable energy technologies and energy efficiency. Partly as a consequence of these developments, a number of small scale niche technologies that were considered “hopeful monstrosities” twenty years ago, have meanwhile developed into veritable industries. Photovoltaic electricity generation and wind power are two cases in point. But also irrespective of environmental public policy priorities, energy sector structures will experience strong pressures for transformation due to new information and communication technologies, which allow for radically different system layouts and open up perspectives for more distributed generation and smarter grid configurations. Finally, also the changing geography of energy innovation has to be reconsidered. Emerging and developing countries are becoming increasingly important players in the quest of future energy systems. Many are considering options for leapfrogging towards higher shares of renewables, circumventing problems of greenhouse gas emissions and nuclear waste associated with conventional technologies.

Based on this state of affairs, the present report builds on an understanding that transformations in the energy sector are likely to be highly complex and will run over several decades. Technological and social aspects have to be considered in their systemic interplay. A literature that has addressed innovation in a socio-technical systems perspective has emerged over the past thirty years under the label of “innovation systems”. The present report takes stock of innovation systems research in its application to energy related problems. It thus aims at providing an overview of current trends and challenges in energy related innovation systems research. It focuses on major conceptual, methodological and empirical developments and identifies areas for promising future research.

In the following section, we will provide an overview of energy research that applies innovation systems concepts. Among the different sub-orientations of national (NIS), regional (RIS), sectoral (SIS) and technological (TIS) innovation systems, the TIS tradition has been by far the most productive in the energy field. Scholars using the other approaches have started to consider energy problems as a legitimate field of application but have not yet developed coherent research programs in this field. We will review that major research lines and work out similarities and complementarities among these traditions. In the third section, we will elaborate in some detail the current conceptual, methodological and empirical challenges that have been identified in the TIS literature. Section four provides a detailed and encompassing overview over the most recent academic literature on energy innovation systems. Section five concludes by discussing the prospects of an emerging “energy innovation systems” agenda and proposes some avenues for future research.

2 Energy innovation system research: different perspectives

The origins of the innovation systems concepts can be traced back to the late eighties, when the national system of innovation concept was formulated (Lundvall, 1992). It was developed in order to provide a conceptual framework for technology and innovation policy for national (and international) policy makers, emphasizing the role of institutional framework conditions and the evolutionary nature of innovation processes. The innovation system perspective was explicitly conceived as a counterpoint to policy advice stemming from the neo-classical economics tradition, which was perceived as providing no explanation for the major economic challenges of the 1980ies, like the rapid raise of Japan as a technology leader (Sharif 2006). The core assumption was that nationally specific institutional arrangements between science, policy and industry explained differences in innovation success among different countries (especially the technology leaders US, Germany and Japan). Particular institutional arrangement which were analyzed encompass the science-industry interface, the availability of venture capital structures, specific industrial policy programs or a broader cultural context supporting innovativeness. The totality of these institutional arrangements was understood as constituting a more or less coherent "national system" supporting (or hindering) the generation of novelty. Besides the structural components, emphasis was also put on processes like learning (learning by doing, by using, by interacting, etc.) and exchanges among different kinds of actors (e.g. user-producer relationships, science-industry co-operations, industrial networks). These concepts were applied to core industries in the leading industrialized countries (like the automobile industry, consumer electronics, the machine tool industry or pharmaceuticals). Geographically this literature had therefore originally a strong focus on Japan, the US and Germany.

Later work on innovation systems accepted most of these initially set assumptions. Basically, all newer proposals acknowledge the importance of analyzing the systemic interplay between actors, networks and institutions and also they extend and differentiate the process concepts. However, the alternative concept variants called SIS, RIS or TIS started with a strong critique of the original NIS literature: the major shortcoming was seen in the *a priori* delimitation of systems along national boundaries. Essentially, RIS, SIS and TIS claim that systemic coherences are often following regional, sectoral or technological logics which may crisscross national boundaries. An exclusive focus on innovation within specific national boundaries either risks missing out on important boundary crossing structures and processes or then averages out over a too broad and incoherent assemblage of such elements. Therefore the set of the four innovation system approaches is best characterized as providing different (and probably quite complementary) vantage points for analyzing similar kinds of objects (namely the systemic interplay between actors, networks and institutions) rather than competing theories.

Energy or other cleantech sectors did not feature prominently as an empirical application field in the early NIS writings. This has to do with their taken for granted character, low innovation intensity of public services sector and a rather low level of attention that was paid to global environmental problems and energy security in the early eighties (being a sort of interlude in between the oil crises of the 1970ies and the emerging global climate change and sustainability debate unfolding in the 1090ies). A notable exception was a paper from Chris Freeman (1996) where he ventured into the possibility that cleantech could become the basis for a 6th Kondratieff cycle leading to a new wave of technological innovation and widespread prosperity. However, this very thought-provoking contribution seemed not to leave a strong mark on the quickly enfolding mainstream of the innovation systems literature and as a consequence it did not provoke a lot of resonance in the NIS, RIS and SIS communities.

Technological innovation and sectoral change processes driven by environmental concerns were more prominently researched in an emerging sub-community within the field of innovation studies. This new field has become known under the label of “sustainability transitions studies” (see Markard et al. 2012; van den Bergh et al 2011). Transition studies are concerned with historical transformation processes of socio-technical systems such as energy supply or transportation (Geels et al., 2012). Within the sustainability transitions community, innovation systems concepts feature prominently, however mostly in the variant of technological innovation systems (TIS). In the TIS tradition quite an impressive range of empirical accounts of emerging industries in the energy and other clean-tech sectors has been developed (e.g. Jacobsson and Johnson, 2000; Jacobsson and Bergek, 2004; Negro et al., 2007; Markard et al. 2009; Dewald and Truffer, 2011). The other variants (NIS, RIS and SIS) have been rather absent from this discourse.

As a consequence, we will split the review on energy innovation systems research in two parts. In the following section, we will give an overview of energy related innovation systems research referring explicitly to the RIS, NIS or SIS perspective. The later sections will then exclusively deal with the development and key findings gained within the TIS tradition. Despite the main focus on TIS research, we argue that there still is a high degree of conceptual overlap and the specific innovation system approaches can be seen as providing largely complementary evidence. We will return to this point in section 2.4.

2.1 Energy research in the NIS, RIS and SIS perspective

As energy and cleantech are rather marginal empirical application fields within the three perspectives NIS, SIS and RIS, we adopted an inductive approach to analyze the literature. An extensive search in the Scopus data base[1] provided 194 academic papers that were explicitly mentioning the term “innovation system” and addressing some energy related empirical problem. Among these publications, however only 35 did not draw on the technological innovation system concept. This general result corroborates the impression that NIS, SIS and RIS approaches have not yet identified energy as a strong and coherent field for empirical investigation. A large share of these 35 papers relates to specific renewable energy technologies like bio-energy, wind, photovoltaic, fuel cells or energy efficiency in the building sector (16). About the same number of papers (14) addresses generic topics such as renewable energy in general or even clean-tech. A couple of papers either focus on specific policies (e.g. European emission trading system, ETS) or non-renewable energies (nuclear power or carbon capture and storage technologies, CCS). Over time, we see a slight recent increase: 19 out of the 35 publications were published in the last two and a half years (2010-2012).

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[1] Search string: TITLE-ABS-KEY("innovation system*" OR "system of innovation" OR "regional innovation system*" OR "regional system of innovation" OR "national innovation system*" OR "national system of innovation" OR "sectoral system*" OR "sectoral innovation system" OR "sectoral system of innovation" OR "regional innovation system*" OR "regional system of innovation" OR "technological innovation system*" OR "technological system of innovation") AND TITLE-ABS-KEY(photovoltaic* OR "PV" OR wind OR "wind power" OR solar OR biofuel* OR "bioethanol" OR "micro-CHP" OR "CHP" OR "combined heat and power" OR "carbon capture and storage" OR "CCS" OR "energy system" OR "electricity system" OR "energy system" OR "smart grid" OR hydrogen OR "fuel cell*" OR "renewable energy" OR "wind energy" OR "biomass" OR "biogas" OR "energy" OR "sustainable energy" OR "bioenergy" OR "low carbon" OR hydro OR "hydro power" OR nuclear OR coal OR "coal power" OR "natural gas" OR "biomass gasification" OR "gas power" OR "natural gas")

However, we have to take into account that quite an important share (about 10%) of the database entries are conference proceedings and not publications in peer reviewed journals, which reinforces the overall impression of energy being not yet a strong field of application for these approaches.

The majority of the selected papers (17) subscribe to a NIS perspective. Some discuss the impact of national regulatory pressures to develop renewable energies (Gebhardt 2002), especially under the conditions of being implemented in an infrastructure sector (Walz 2007). An important question is here whether strong environmental regulations lead to longer term technology leadership of a country as suggested by the famous Porter and van der Linde (1995) hypothesis and what intermediating role accrues to specific NIS structures in this regard (Constantini and Crespi 2008). More structure oriented approaches focus, for instance, on the role of the vocational education system for the success of specific technologies (e.g. for fuel cells see Hung and Chang 2011) or the role of specific organizations like the applied technology research centre system VTT in Finland (Kutinlahti and Hyytinen 2002). Others show how specific national institutional arrangements explain the success of certain energy innovations (like bioethanol in Brazil, see Furtado et al. 2011) or how specific institutions like standards are based on specific features of the NIS (De Souza and Hasenclever 2011). NIS approaches are often applied to the analysis innovations in emerging economies and developing countries. Here, issues like technology transfer or leapfrogging are addressed (e.g. Fu and Zhang 2011). A particularly interesting argument is elaborated by Provance et al. (2011) who analyze the role of specific NIS structures for successfully developing new business models for micro-generation. By this they propose to connect system structures with the strategies of individual firms.

Among the papers that explicitly refer to the SIS framework (10) there are quite a few which define the term sector rather synonymously with specific technologies (like photovoltaics, wind or bioethanol). The difference between these approaches and TIS studies seems not all too clear-cut, especially for those cases that deal with emerging industries (see for instance Kristinsson and Rao 2008; Marinova and Balaguer 2009; Kedron and Sharmistha 2009; Vidican et al. 2008). Marinova and Balaguer (2009) are particularly interesting as they adopt a comparative framework for analyzing PV industry formation in Germany, Japan and Australia and using differences in the respective NIS structures as explanatory variables. More specific sectoral approaches ask for the implications of external factors impacting the energy (or housing) sectors on radical innovations. Some authors conclude that SIS tend to strongly favor incremental innovations (Kubeczko et al. 2006 or Beerepoot and Beerepoot 2007) whereas others see positive impacts on the promotion of renewable energies depending on the kind of external stimulus (e.g. for the case of the EU ETS, see Rogge and Hoffmann 2010 or for oil prices see Cheon and Urpelainen 2012).[2]

The RIS perspective (5 papers) mostly confirms that regional innovation systems structures and innovative clusters actually represent very conducive backgrounds for energy innovations (Cooke 2010; specifically for fuel cells see Madsen and Andersen 2010). Some of these studies emphasize the

2 There is likely a much broader discourse on conditions for innovation in the energy sectors that was not captured by our search string. Namely, the impact of specific institutional reforms on the inclination of electric utilities to move into radical innovations or not would be a case (see for instance Markard and Truffer, 2006). This larger literature was not included as it does not explicitly refer to an innovation system framework.

importance of specific institutional structures like regional technology innovation centers for supporting innovations in the energy sector (Goddard et al. 2012).

Overall, we can conclude that a small, but recently growing stream of innovation system research on energy outside of the technological innovation system tradition exists. The literature is quite diverse though and not well developed for providing a coherent perspective on energy innovations. Also, as all innovation systems approaches focus on a diversity of actors, their networks and institutional arrangements, the different perspectives often come to very similar conclusions and it is hard to tell where the added value of each of the approaches lies. This is especially true for those examples which focus on specific technologies (like photovoltaics, wind, fuel cells, etc.). Starting from this assessment, we will now present the – more vibrantly developing – TIS approach to energy innovation in some more detail. In section 2.4 we will come back to the question how the different IS perspectives might complement each other.

2.2 Development of the TIS perspective

Research on technological innovation systems (TIS) has emerged as major line of inquiry in the broader field of transition studies (Markard et al., 2012). The TIS framework is well suited to study emerging industries that develop out of radically new technologies and the institutional and organizational changes that have to go hand in hand with technology development. Below, we briefly review the emergence of the framework and its main lessons.

The TIS concept can be traced back to the seminal paper of Carlsson and Stankiewicz (1991) that highlighted the systemic interplay of firms and other actors under a particular institutional infrastructure as the essential driver behind the generation, diffusion and utilization of technological innovations. The authors relate their concept primarily to Dahmén's work on development blocks which are constantly evolving systems centered on a generic technology (Dahmen, 1988; Enflo et al., 2008). There are also linkages to the concepts of national innovation systems (Freeman, 1988; Nelson, 1988), regional and sectoral innovation systems (Cooke et al., 1997; Malerba, 2002) and the innovation systems approach formulated by scholars at Lund University (e.g. Edquist, 1997).

In the 1990s, TIS research focused on a variety of systems, which were delineated in various ways. Some focused on a specific field of knowledge, such as microwave engineering, a particular material technology or biocompatible materials. Others were delineated by a product (e.g. CNC machine tools) or product group (e.g. factory automation) whereas yet others had a sectoral focus, such as electronics industry or biomedical industry. Some of these systems were mature whereas others were in an early phase of development.

The framework has seen several conceptual refinements (Carlsson et al., 2002), one of the most influential being the identification of key processes, so-called functions (see table 1), which need to run smoothly for the system to perform well (Johnson, 2001; Johnson and Jacobsson, 2001; Jacobsson and Bergek, 2004; Hekkert et al., 2007; Bergek et al., 2008a). Other conceptual contributions have directed attention to the complementarities of TIS and the multi-level perspective (Markard and Truffer, 2008b; Coenen and Diaz-Lopez, 2010), to prospective technology analyses (Markard et al., 2009), to the interaction of different technological innovation systems (Sanden and Hillman, 2011; Wirth and Markard, 2011) and to processes of system building (Hellsmark and Jacobsson, 2009; Musiolik and Markard, 2011; Musiolik et al, 2012; Dewald and Truffer, 2011).

Table 1: Key processes in technological innovation system build-up

Key process	Definition	Indicators
Knowledge creation and diffusion	Activities that create new knowledge, e.g. learning by searching, learning by doing; activities that lead to exchange of information among actors, learning by interacting and learning by using in networks	R&D projects, no. of involved actors, no. of workshops and conferences, network size and intensity, activities of industry associations, websites, conferences, linkages among key stakeholders
Influence on the direction of the search	Activities that positively affect the visibility of requirements of actors (users) and that have an influence on further investments in the technology	Targets set by the government, changes in regulatory frameworks, no. of press articles that raise expectations, visions and beliefs in growth potential
Entrepreneurial experimentation	Emergence and decline of active entrepreneurs as a prime indication of the performance of an innovation system, concrete activities to appropriate basic knowledge, to generate and realize business opportunities	No. of new entrants, no. of diversification activities of incumbents, no. of experiments
Market formation	Activities that contribute to the creation of demand or the provision of protected space for the new technology, e.g. construction of market segments	No. of niche markets, specific tax regimes and regulations, environmental standards
Creation of legitimacy	Activities that counteract resistance to change or improve taken-for-grantedness of new technologies	Rise and growth of interest groups and their lobbying activities
Resource mobilization	Activities related to the mobilization and allocation of basic inputs such as financial, material or human capital	Availability of competence/human capital, financial capital, complementary assets for key actors
Development of positive externalities	Outcomes of investments or of activities that cannot be fully appropriated by the investor, free resources that increase with number of entrants, emerge through firm co-location in TIS	Emergence of pooled labor markets, intermediate goods and service providers, information flows and knowledge spill-overs

Source: Compiled from (Bergek, Jacobsson, Carlsson, Lindmark, et al. 2008a; Hekkert, Suurs, Negro, Kuhlmann, et al. 2007; Musiolik and Markard 2011)

From their beginning, many analyses of technological innovation systems were intended to inform policy making (Carlsson et al., 2002) which is why the identification of drivers and barriers to innovation is a typical task performed in TIS studies (Carlsson and Jacobsson, 1997; Bergek and Jacobsson, 2003; Jacobsson and Bergek, 2004; Jacobsson and Lauber, 2006; Negro and Hekkert, 2008). In fact, one of the major contributions of the innovation systems perspective is that it has left behind and replaced the narrow concept of market failures by a broader set of system weaknesses (or system failures), expressed either in structural and/or functional terms (Carlsson and Jacobsson, 1997; Bergek et al., 2008a; Jacobsson and Johnson, 2000; Klein Woolthuis et al., 2005; Kuhlmann et al., 2010; Weber and Rohracher, 2012). Combined with the aforementioned shift towards technology-specific innovation systems this has paved the way for suggesting technology-specific policies on the basis of TIS analyses (Carlsson and Jacobsson, 1997; Jacobsson and Bergek, 2004; Jacobsson and Bergek, 2011; Sandén and Azar, 2005; Azar and Sandén 2011).

Energy has always been a very prominent topic both in the broader field of sustainability transitions and in research on technological innovation systems. One of the early major contributions is Jacobsson and Johnson (2000), in which the authors explore the development of renewable energy technologies and discuss barriers to their diffusion on the basis of an innovation systems perspective.

Many influential papers have followed since then, including studies on renewable energy technologies in general (e.g. Jacobsson and Johnson, 2000; Johnson and Jacobsson, 2001) as well as more specific analyses on photovoltaics (e.g. Jacobsson et al., 2004; Dewald and Truffer, 2011; Dewald and Truffer 2012), wind energy (e.g. Bergek and Jacobsson, 2003; Markard and Petersen, 2009), biomass (e.g. Jacobsson, 2008; Negro et al., 2007; Negro and Hekkert, 2008; Wirth and Markard, 2011; Markard et al. 2009), biofuels (e.g. Suurs and Hekkert, 2009 and Hellsmark, 2010), carbon capture and storage (van Alphen 2010) or fuel cells (e.g. Markard and Truffer, 2008a; Musiolik and Markard, 2011; Konrad et al., 2012). This shift towards focusing on energy related innovations was accompanied by a greater attention to innovations in an early stage of development with a potential to challenge established socio-technical systems. In other words, over the years the analytical interest in TIS research shifted from general technological innovations contributing to the economic growth of countries to new (energy) technologies as nuclei for fundamental socio-technical transitions (see figure 1).

A typical characteristic of many of these later studies is that a selected energy innovation is studied in the context of a particular country, given the national regulatory and industry structures. Some researchers have also compared the development between different countries but this has rather remained the exception (e.g. Bergek and Jacobsson, 2003; Jacobsson and Bergek, 2004, Hellsmark, 2010; van Alphen, 2010). Only recently, scholars have begun to go beyond the initial national study setting with regional and global analysis of the structures of technological innovation systems (Coenen et al., 2012; Dewald and Truffer, 2012; Binz, et al. 2012).

Regarding their geographical focus, energy related TIS studies have mostly developed by European research groups from Sweden (Chalmers), the Netherlands (Utrecht), Switzerland (Eawag) or Austria (ARC and IFZ). More recently, the concepts have been taken up in emerging economies like China or Brazil. In the US, a concept named “energy technology innovation systems” (Gallagher et al. 2012) was presented that builds (although selectively) on some of the larger TIS literature.

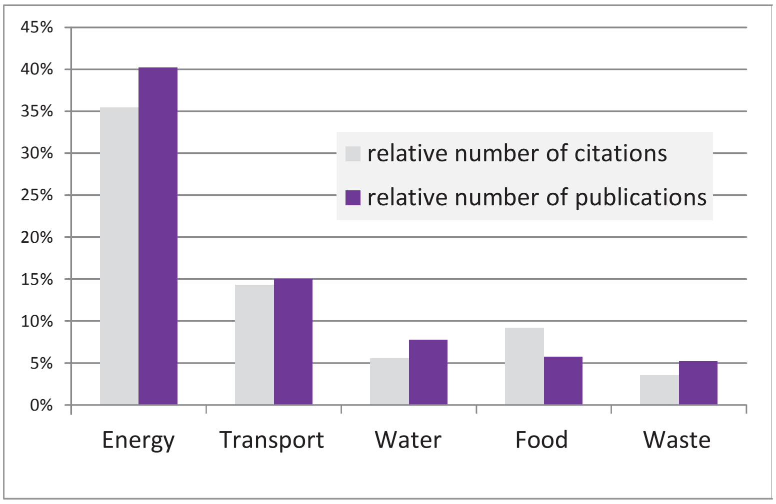

Figure 1: Relative importance of energy as a topic in the broader field of sustainability transition studies (Markard et al., 2012)

2.3 Major lessons from TIS studies on new energy technologies

TIS studies on emerging energy technologies have generated a number of insights, which are key to understand the dynamics we observe in the field and to derive policies to foster energy innovation systems. Some of these insights also relate to the broader characteristics of energy sectors as being constituted by well-established socio-technical regimes and an infrastructure that is capital intensive, durable and highly systemic (Markard 2011). This implies that there is a high degree of inertia due to strong vested interests (economic and political) and a high technical and institutional interdependence of system components. As a matter of fact, the general type of innovation is incremental and radical socio-technological change is rather the exception.

- **Lock-in:** New energy technologies that deviate from established structures (e.g. distributed electricity generation) have a hard time to develop because the energy sector is very much locked into established technologies; existing institutional, organizational and political structures support the established technologies; in the electricity and gas sector, lock-ins are aggravated due to the capital intensity and durability of existing technologies and network infrastructures; lock-in is prevalent on the supply as well as on the demand side.
- **Uncertainty and risks:** Energy innovations are characterized by major uncertainties for investors and policy makers; risks are high as a result of uncertainty.
- **Environmental impacts:** A key driver for energy innovations are negative environmental impacts of existing technologies; energy and environmental policies are often closely intertwined.
- **Energy sector as a public service sector:** The energy sector is characterized by a high degree of regulation (due to its societal importance and because of network monopolies); public authorities as well as public service companies play a crucial role in many countries; these characteristics make the energy sector distinct from other service sectors.
- **Politics:** Strong vested interests and an active pursuit of these interests is characteristic for the domain of energy policy-making and thus a crucial component in the dynamics of new energy technologies.
- **Complexity & idiosyncrasy:** A large variety of factors play a role for emerging technologies, there is no optimal structure or recipe of how to develop a technology successfully, each technology and context has its particularities.
- **TIS structures:** For new energy technologies to develop and diffuse, supportive institutional and organizational structures including technology-specific policies are required; supportive structures partly emerge but they are also developed strategically by the actors in the field.
- **TIS performance:** TIS performance can be best assessed on the basis of key processes (functions); it is not sufficient to look at TIS structures alone to understand whether an emerging technological system is performing well or not.
- **TIS context:** Apart from the TIS itself, context developments (e.g. at the NIS or SIS level) play a crucial role for new technologies; these include the ups and downs of existing technologies and established socio-technical systems as well as of competing and complementary technological innovations. The TIS context is also the source of actors, competences (e.g. human resources), material and financial resources etc.
- **TIS life cycle:** TIS in early stages of development (e.g. fuel cell technology) may require different support than more mature systems (e.g. wind energy); in immature TIS technological expectations and legitimacy play a much more decisive role, for example.

2.4 Towards an integrated agenda on “energy innovation systems”

The above literature review has shown that energy is a prominent topic in innovation systems research. The TIS perspective has developed quite an elaborate set of empirical case studies and conceptual tools to address conditions for success of energy innovations, particularly if they imply a more radical restructuring of the prevailing energy sectors. Increasingly, we see contributions from the other innovation system schools (NIS, RIS and SIS) that aim at tackling problems of energy innovation processes. As mentioned earlier, these different approaches rather complement each other, which is why it might be a worthwhile endeavor to explicitly compare the contributions of the different perspectives to the explanation of emerging (energy) technologies.

The conceptual complementarities can be explored along different lines. Among these are comparative designs of different TIS-structures and processes that are located in different national contexts. Another promising inroad could be the connection between NIS approaches and management studies research on emerging business models and value chain creation (such as in Provance et al. 2011). Also, the NIS perspective certainly emphasizes the role of macro-institutional conditions such as the prevailing science system, regulations on property rights, synergies among different aspects of industrial policy, national cultural preferences, etc., which might be overlooked in studies that are narrowly focusing on single technologies. In a similar vein, the RIS perspective focuses even more explicitly on existing industry networks and their embedding in local and regional cultures, the importance of regional labor markets, university systems, etc. Strong institutional embedding was shown to be decisive for overcoming the high levels of uncertainty typical for early energy innovations (Dewald and Truffer, 2012). Finally, a SIS perspective is very attentive to the role of incumbent actors in the energy system, their likely support or opposition to developments in certain technological fields (Erlinghagen and Markard, 2012). Furthermore, the impact of large scale institutional reforms (such as privatization, deregulation or liberalization) on the innovation management in a whole sector might be more consistently analyzed when a sectoral focus prevails.

Therefore, we see a high added value in striving for a more integrated view on “energy innovation systems”. As this potential has not yet been widely identified and no overarching “energy innovation system community” exists yet, we propose to discuss potential inroads to a broader agenda starting from current research needs that have been identified within the TIS community.

3 Major challenges in developing the TIS research agenda[3]

Despite the recent progress in TIS studies, there are several conceptual and methodological challenges still pending. In the following we list some key topics where future research seems to be particularly beneficial.

3.1 Core concepts

a) General

It is widely acknowledged that actors and institutional structures are the key elements (or components) of technological innovation systems. Actors and institutions are interrelated through different kinds of networks and commonly contribute to the development of diffusion of a novel technology. However, recent contributions have also suggested differentiating further TIS elements, including technology, knowledge, or system resources (e.g. Bergek et al. 2008a; Sandén and Hillman, 2011; Musiolik and Markard, 2011). System resources, for example, can be a useful concept to explain the system-building strategies of TIS actors and the resulting positive externalities.

b) Functions concept revisited

The system functions are one of the major innovations of the TIS concept in recent years. They have triggered a whole wave of empirical studies and many new insights. At the same time, the concept has also created some confusion as different scholars have a different understanding of what functions actually are and whether the term as such is misleading or not (Bergek, 2012). Moreover, it is still unclear whether we have already come up with a sufficient set of (seven) functions or whether there are any functions missing (e.g. value chain creation or system building, cf. Musiolik and Markard, 2011 and Musiolik et al, 2012). Another topic that requires further attention and conceptual reflection is the relation between TIS structures and functions.

c) Actors, networks and intermediaries

The predominant view on TIS actors is that they are working together (mostly implicitly through the guidance of institutional structures) towards the overall system goal, which is the development and diffusion of the focal technology. However in empirical analyses, we see that firms often pursue specific strategic interests, e.g. as they positively communicate and inflate the prospects of 'their' technology (Konrad et al., 2012) or support specific standards that match their already existing competences (Musiolik and Markard, 2011). Firms and other actors also contribute to system building in a strategic way (Musiolik et al, 2012). Against this background is it essential to further our analysis of actor roles and strategies in TIS studies (cf. Farla et al., 2012).

So far, the TIS concept distinguishes different kinds of actors in a very generic sense, i.e. firms, policy makers, research institutes, NGOs etc. At the same time, the concept of (actor) networks plays a key role for TIS scholars. While there is a common understanding that networks are important, e.g. for knowledge exchange in innovation systems, we are just at the beginning to understand alternative

[3] The radar paper profits from synergies of a number of ongoing international initiatives in the field of energy innovation systems research. In particular, Section 3 is aligned with an ongoing initiative of an international group of scholars contributing to the TIS literature to elaborate and specify the TIS research agenda.

roles of networks. Recent research has shown that (formal) networks can play a crucial role for TIS formation and the development of supportive institutional structures in a TIS (Musiolik et al., 2012). A novel and more specific conceptualization of actors (including networks and intermediaries) could therefore address their role in system building.

d) Concept of Institutions

Regulatory, normative and cognitive institutions play a key role for the development and diffusion of innovations. In fact, it is the dynamic interplay of institutions and organizations that largely determines the course of technology development. Despite the importance ascribed to institutions and institutional change, there is little consensus on how to systematically analyze institutions and their role in innovation processes in general and technological innovation systems in particular. This is all the more striking in fields such as 'sustainable innovations', where environmental regulations, public support programs and normative views can be strong institutional drivers, while at the same time the technology is opposed by established institutional structures that support less sustainable technology alternatives.

What will be needed is a more elaborated conceptual understanding of institutions and the interplay of institutional structures for the development of new technologies. In addition, we will have to address the question of how actors strategically change and create institutional structures (cf. sub-section 3.1.c).

e) TIS life-cycle and transitions

Scholars working with the TIS approach have not yet developed a conceptual framework that explicitly elaborates on the evolution of innovation systems over time or explains socio-technical transitions, i.e. fundamental, multi-dimensional changes of established socio-technical systems through innovation system dynamics. Such a "TIS based" transition framework could deliver insights that are complementary to the already established multi-level perspective (e.g. Rip and Kemp, 1998; Geels, 2002). In parallel, conceptual development will have to concentrate on the life-cycle of technological innovation systems, i.e. the particularities and dynamics that occur when a TIS develops from a very early, embryonic stage into more mature structures with different system properties (e.g. dominant design, path-dependencies).

3.2 Methodological issues

a) Measurement of functions:

A central task in a TIS analysis is to assess the strength of the functions. This can be done in a number of ways which include conventional indicators such as patents, but also less conventional ones such as measures of the supply of specialized human capital and of the legitimacy of a new technology. Interview based assessments are common (e.g. Hellsmark, 2010). Negro et al. (2007) and Suurs et al. (2009) combine these with quantitative analyses of events. Van Alphen (2011) uses expert assessment to quantify the strength of the functions in five countries. A number of tools have, thus, been tried but as yet, no standard combination of indicators for measuring the strength of the functions has been developed. A research task would be to review and empirically test possible indicators for each function, the aim of which is to recommend a standard set of indicators that allows for comparisons across technologies, time and space in the field of environmental innovations (Jacobsson and Bergek, 2011).

b) System boundary setting

In many TIS studies, system boundaries are defined ad hoc and without much consideration of the implications this has for the findings. Applying national boundaries, for example, becomes increasingly problematic as TIS in the energy sector typically span many countries and even develop into global industries (as in the case of PV or wind energy). Future research has to engage more explicitly with the question of how to conceptualize and identify system boundaries. We might also want to compare the suitability of boundaries that are defined from the beginning of a study with an emerging boundary setting in the course of the analysis (e.g. Bergek et al., 2008a, Carlsson et al., 2002).

c) Extending the methodological tool-box

As network formation is arguably of key importance for TIS emergence and performance, social network analysis promises a new and more formalized methodological inroad for analyzing how actors get connected to each other and how they jointly develop a conducive environment for innovation. Promising fields of application comprise the identification of spatial and technological boundaries of TIS (Binz et al. in preparation, Sanden and Hillmann, 2011), in-depth analysis of actor networks underlying specific TIS functions or explanations on the determinants of successful or failing cooperation among complementary actor groups. So far, TIS studies have not made much use of recent advances in the modeling of socio-technical transitions (cf. Safarczynska et al. 2012). From these and other new methods we expect interesting, complementary insights to the more 'traditional' TIS analyses prevailing up to now.

d) Predictive models and strategic planning

Recent work in TIS has ventured into developing the concepts further for forward looking contexts. Markard et al. (2009) for instance presented a method for "innovation system analysis" that identifies alternative coherent techno-organizational variants that could represent potential but not yet realized development trajectories for a specific TIS. In that context, scenario methods gained increasing attention as a means to identify future context conditions, which would support or hinder the further development of TIS (see e.g. Truffer et al. 2008). Along these lines, other research has ventured into identifying specific capability constellations represented by alternative value chain configurations. These enable the identification of future development prospects TIS (e.g. for the urban water management sector see Gebauer et al. 2012). These methods are likely to have an important role to play in future attempts to connect TIS analysis with the management literature (see 3.1.c) and probably also in the context of technology policy (see 3.4).

3.3 Considering contexts more explicitly

If we think of technological innovation systems as socio-technical systems that do not just exhibit specific 'internal' dynamics but are also affected by developments in a broader context (e.g. new technologies that emerge in adjacent sectors), then we will need a more elaborated understanding of context structures and context dynamics.

a) Spatial contexts: National, regional, global, multi-scale

Space has been absent from much of the actual TIS research (Carlsson, 2006; Coenen et al., 2012; Truffer and Coenen, 2012; Coenen and Truffer, 2012). Only very recently, TIS studies have started to address the implications of regional embedding (Dewald and Truffer, 2012) and the international and global dimensions of technological innovation systems (e.g. how global developments in a specific technological field affect the TIS in a selected country (cf. Binz et al., submitted). Therefore, we expect TIS research to greatly benefit from addressing issues such as how technological innovation systems connect on a regional, national and global scale or how to analyze the geographical reach of TIS (cf. 3.2b).

b) Sectoral contexts/regimes

The review of different innovation system perspectives above has highlighted the potential that rests in a more systematic exploration of the overlap and intersection of emerging and established systems of innovation. Future research should address questions such as the following: How do TIS interact with established socio-technical regimes? How do TIS link up with established institutional fields (cf. section 3.1d)? It would be desirable to introduce a more elaborate analysis of established sectoral systems (or socio-technical regimes) as specific context elements and analyze more comprehensively how they affect the TIS under study (cf. Markard and Truffer, 2008b; Wirth and Markard, 2011). This then facilitates the analysis of the interplay of incumbent and emerging technologies (e.g. nuclear and renewable energies) in a similar way as scholars who use the multi-level perspective (Geels, 2002) do.

c) TIS context and TIS – TIS interaction

Another way to structure the context is to include other technological innovation systems that affect the focal TIS either in a complementary or in a competitive way (or both) (Jacobsson, 2008; Sanden and Hillmann, 2011). For the case of biogas, Wirth and Markard (2011) have shown how the emerging TIS for Bio-SNG in Switzerland was hampered by the developments in various technological fields that compete for the same biomass resources (here: wood).

3.4 Policy implications

As mentioned above, the TIS framework was developed as a policy tool to guide policy makers in designing interventions which were specific to a particular system. Implementing such policies raises the question of how policy makers can identify the processes that are of critical importance to the dynamics of specific technologies and to which policy intervention should be addressed. The prime contribution of TIS-related analyses, so far, has been to use the functions of innovation systems as a tool for pinpointing system weaknesses which then act as a guide for policy makers (Jacobsson and Bergek, 2011). Of course, other actors interested in influencing system dynamics (individual firms, networks of firms, academics, interest organizations) may also use system weaknesses as a guide for their actions (investment, lobbying etc).

More work is required along at least two lines. A first is the competence, organisation and integrity of public policy bodies. Identifying relevant system weaknesses necessitate that policy makers have a high analytical and deep domain-specific competence. Moreover, using system thinking implies that a range of government bodies needs to be involved in the analysis and implementation of policy.

Competence to coordinate policy intervention must, therefore, exist. Analysing the competences and organisational set-up required to implement TIS in policy making is, therefore, a worthwhile field for research. Second, a system approach implies that we should think of policy instruments as “systemic instruments” that are applied to deal with system weaknesses. These instruments go much beyond the neoclassical focus on relative prices etc. and include e.g. instruments to strengthen the legitimacy of new technologies. More work is required to specify the range of “systemic instruments” and assess their usefulness in various contexts (Weber and Rohracher 2012, Wieczorek and Hekkert, 2012).

4 Development trends in the most recent energy EIS literature (2010-2011)

We will now turn to a quantitative and qualitative overview of the recent energy TIS literature. This section will reflect the thematic foci of the research agenda sketched in section 3 with recent publications and aims at triangulating these agenda dimensions with recent work in the field. A comprehensive literature research in the Scopus database was conducted, covering publications from 2010 and 2011. The search was structured in three consecutive steps (see figure 2): First, papers that contribute to the conceptual core of technological innovation systems were identified and categorized into thematic clusters. Then, these results were complemented with a very broad search string (looking for 'innovation', 'energy' and 'system') resulting in a large but mainly unfocussed set of publications that provide a feeling for the larger scholarly context of energy TIS research. Finally, publications that combine an innovation system focus with the most popular empirical fields in the wider context were categorized according to the thematic clusters developed in step 1.

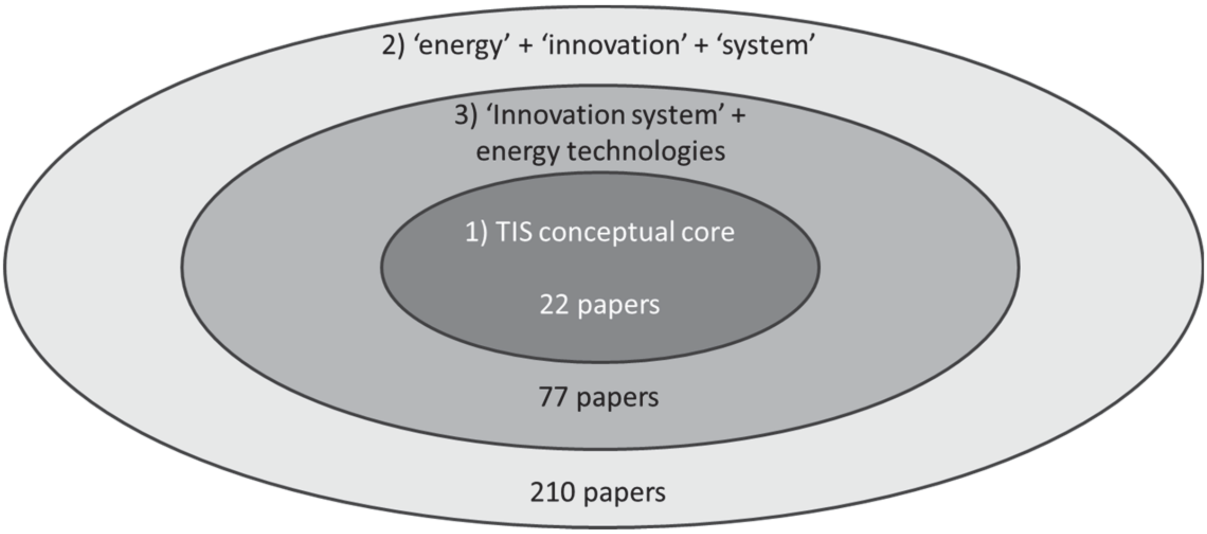

Figure 2: Scheme of analysis and number of identified papers

4.1 Publications in the conceptual core of TIS research[4]

21 papers in the Scopus database between 2010 and 2011 contained "technological innovation system" in the title, keywords or abstract. 18 of them contribute directly to the TIS concept. Except for four papers (Binz et al., 2011), Jacobsson and Perez-Vico (2010), Pellegrin et al. (2010) and Leydesdorff and Zawide (2010)) all authors strongly base their contribution on energy related case studies. 4 papers by Chinese authors were excluded from the analysis as they use the term "technological innovation system" as a buzzword in an unrelated context (e.g. patent network analysis, systems theory, empirical cases in the Chinese defense sector), without or only with 'pro forma' reference to TIS literature.

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[4] Search string: TITLE-ABS-KEY("technological innovation system") AND (PUBYEAR = 2010 OR PUBYEAR = 2011) AND SRCTYPE(j)

Five papers had to be added to this list as they contribute to TIS research, but do not name the concept in the title, abstract or keywords (Jacobsson and Bergek 2011, Meijer et al. 2010, Jacobsson and Vico 2010, Smith and Grin 2010 and van den Bergh et al. 2011). 22 core conceptual papers thus remained for a detailed analysis.

Five thematic clusters emerged inductively out of this literature review: i) Policy / governance of TIS, ii) conceptual clarifications, iii) actor strategies, iv) functional approach to TIS and v) extending insights from TIS studies to other literatures. The core papers can be allocated to these thematic clusters as follows:

a) Policy implications / Governance of TIS

Authors	Topic	Case study	Country	Concepts	Approach
Jacobsson and Bergek (2011)	TIS policies, system weaknesses	several	diverse	TIS, MLP	Review
Vasseur and Kemp (2011)	Effect of policy on TIS evolution	PV	Germany, Netherlands	TIS	Case study
Hillman et al. (2011)	Framework for analyzing IS governance	none	diverse	TIS, MLP, governance	Review

Policy and the governance of TIS are key topics in three contributions. Two strands of argumentation can be identified in the literature: In the first paper by Jacobsson and Bergek (2011), TIS is used as an approach to formulate policies that sustain diffusion of renewable energy technologies. It is argued that technology specific policies could be derived from a system weakness – based TIS approach and that such an approach could enhance policy advice in a sustainability transitions framework. The other two papers discuss how specific policies and governance modes influence the evolution of innovation systems by applying a political science and governance approach.

b) Considering contexts more explicitly

Authors	Topic	Case study	Country	Concepts	Approach
Sanden and Hillman (2011)	Interaction among technologies in IS	biofuels	Sweden	STS, TIS	Review, case study
Wirth and Markard (2011)	Influence of context factors on TIS evolution	synthetic natural gas	Switzerland	TIS	Case study
Leydesdorff and Zawdie (2010)	Triple helix perspective on innovation systems	several	diverse	Triple helix, IS	Review
Coenen and Diaz Lopez (2010)	Comparison of system approaches to innovation	several	diverse	SIS, TIS, ST-systems	Review
Pellegrin et al. (2010)	Role of innovation networks in IS	oil industry	Brazil	NIS, RIS, SIS, TIS, IN	Review, case study

The thematic cluster focusing on conceptual clarifications and the context of TIS can be divided in to two main streams: The first two papers address basic conceptual elements of TIS and how they relate to the context of a focal TIS. Sanden and Hillman focus on the conceptualization of technology and on how different technologies interact. They argue that technologies have to be conceptualized as socio-technical systems and that beyond competition, other interaction modes like symbiosis, neutralism, parasitism, commensalism and amensalism are possible. Wirth and Markard try to understand how dynamics in the context influences developments inside a focal TIS. They argue that developments in related sectors can be of crucial importance for TIS evolution.

The remaining three papers also discuss how context influences a focal technological innovation, but do so by focusing strongly on related innovation system concepts. They all discuss how (interacting) innovation systems at other levels like NIS, RIS, SIS or a triple helix perspective on IS define the context for a focal TIS.

c) Actor strategies

Authors	Topic	Case study	Country	Concepts	Approach
Musiolik and Markard (2011)	Actors forming strategic networks for TIS buildup	Fuel cells	Germany	TIS, management	Case study
Meijer et al. (2010)	The role of entrepreneurs in innovation systems	Biomass combustion	Netherlands	Entrepreneur ship	Case study

This small thematic cluster revolves around the question how strategic behavior of TIS actors can be conceptualized and analyzed. Musiolik and Markard argue that TIS actors proactively build up strategic networks to sustain specific technologies which in turn provide critical resources to system build up. Meijer et al. take an entrepreneurship perspective and analyze how perceived uncertainty influences the strategic behavior of entrepreneurs in innovation systems.

d) Functional approach to TIS

Authors	Topic	Case study	Country	Concepts	Approach
Dewald and Truffer (2011)	Market formation in TIS	PV	Germany	TIS, management	Case study
Dantas (2011)	Knowledge accumulation in TIS	Biofuels	Brazil	TIS	Case study
Jacobsson and Vico (2010)	Effects of academic R&D on TIS functionality	Diverse	Diverse	TIS	Review
Suurs et al. (2010)	Cumulative causation in emerging TIS	natural gas in transport	Netherlands	TIS	Case study
Praetorius et al. (2010)	Functional TIS analysis	micro-generation	UK, Germany	TIS	Case study
Hudson et al. (2011)	Functional TIS analysis	micro-CHP	UK, Netherlands	TIS	Case study
Van Alphen et al. (2011)	Functional TIS analysis	CCS	US, CA, NO, NL, AU	TIS	Case study

The functional approach to TIS is still the most popular field of activity in energy TIS studies. Papers in this cluster follow two routes of argumentation: The first three papers strive at a more precise conceptualization of processes that work in specific functions or the overall functional pattern of a TIS. So far contributions only focus on the ‘market formation’ and ‘knowledge creation and diffusion’ functions.

The second stream of four publications applies a functional approach to TIS empirically in order to derive implications on cumulative causation processes in early development stages of a TIS or to formulate technology specific policy advice.

e) Extending insights from TIS studies to other literatures

Authors	Topic	Case study	Country	Concepts	Approach
Smith et al. 2010	Potential contributions of TIS to the MLP framework	None	none		Review
Van den Bergh et al. (2011)	Potential contributions of TIS to the MLP framework	None	none		Review
Foxon et al. (2010)	TIS and MLP based transition pathways	Electricity system	UK	MLP, TIS	Review, case study
Binz et al. (2011)	Applying TIS to leapfrogging literature	water recycling	China, global	TIS, leapfrogging	Case study
Huertas et al. (2010)	Using TIS for evaluating stakeholder acceptance	Bioethanol	Brazil	TIS	Case study

Papers from this thematic cluster address the potential fruitful overlaps between TIS and other strands of literature. Most publications define points of mutual interest with sustainability transitions concepts and especially the multi-level perspective on technological transitions (MLP). The first two papers are extended reviews, whereas the third paper tries to develop an analytical framework for analyzing transition pathways based on a combination of TIS and MLP concepts. The last two papers apply the TIS approach as an analytical framework for other related literatures, namely to the literature on technological leapfrogging in newly industrializing countries and as an analytical tool to assess stakeholder acceptance of new technologies.

The above list of thematic clusters was developed inductively and is to be taken as a first indicative overview. Some papers would be attributable to different clusters and others might be categorized differently. As an example the paper by Jacobsson and Bergek (2011) also discusses how TIS and MLP relate to each other, so it could also be attributed to the last cluster. The papers of Binz et al. (2011), Dewald and Truffer (2010) or Dantas (2011) as other examples, all apply a geographic perspective to TIS, so they could also be categorized as a 'geography of TIS' cluster.

Half of the publications in this core group is authored by the largest research groups contributing to the field, e.g. at Chalmers University, Utrecht University as well as at Eawag. Interestingly, three papers cover the biofuel case in Brazil, two of which are authored mainly by Brazilian authors. Contributions to the conceptual core, thus, seem to expand geographically and qualitatively to newly industrializing countries and especially to Brazil.

4.2 The wider scholarly context of energy innovation systems research

In order to complement the above overview of the core conceptual contributions in energy TIS research, another search string containing energy, innovation and system as keywords was used in

Scopus.[5] This broad search string generated 210 results, which however contained many unrelated articles from distant academic fields. 54 engineering based papers were consequently removed from the dataset and the remaining 156 papers were categorized according to their abstracts.

Insights from this extended database:

- Extending the focus reveals about 60 additional papers in the energy field which are more or less closely related to TIS. Overall, about 80 papers (including the ones already discussed in the section above) are interesting in the wider sense for TIS research, though already quite distant from the conceptual core of innovation system studies.
- Most plentiful and fruitful insight might be derived from contributions from political sciences, urban studies, geography, economics and management.
- Empirical fields are very broad: From PV to wind, hydrogen, bio-ethanol, CCS, solar water heater to palm oil and smart grids. Also more aggregated perspectives (renewable energy, low-carbon economy, etc.) are referred to in literature relatively often (see table 2). Renewable energy, biofuels, energy infrastructure, hydrogen/fuel cells, wind and photovoltaics are the core empirical fields (see table 2).
- Interestingly, a few of the listed engineering papers take the socio-economic context of renewable energy technologies into account and apply a socio-technical perspective, by discussing how (especially the economic and in some cases institutional) context of "clean" technologies matters for their success.

[5] TITLE-ABS-KEY("energy" AND "innovation" AND "system") AND (SUBJAREA(soci) OR SUBJAREA(busi) OR SUBJAREA(econ) OR SUBJAREA(busi) OR SUBJAREA(ener)) AND (PUBYEAR = 2010 OR PUBYEAR = 2011) AND SRCTYPE(j)

Table 2: Empirical field of application

Empirical case	Number of papers
none	9
Renewable energy	9
biofuels	7
energy infrastructure	5
hydrogen, fuel cells	5
photovoltaics	5
wind	5
climate change mitigation	4
energy policy	3
Environmental governance	3
low carbon society	3
Carbon capture and storage	3
eco-buildings	2
micro-generation	2
coal power	1
factory automation	1
global energy modeling	1
green regions	1
micro-CHP	1
natural gas	1
water	1
palm oil	1
energy input prices	1
Renewable energy policy	1
smart grid	1
solar water heater	1
advanced geothermal systems	1
Total	78

- Bioethanol and biofuels are a surprisingly popular empirical field which appears to be booming especially in case studies in Brazil
- A majority of contributions is focusing on renewable energy technologies, only very limited number of papers refers to conventional power generation technologies like natural gas or coal power
- Modeling and especially economic models in the renewable energy field are relatively popular and applied in many studies with an economics background
- Policy analysis, especially of interventions for sustainable energy (and assessment of policy intervention) is booming recently.

4.3 Triangulating the conceptual core and empirical context of energy TIS research

In a last step, a search string containing "innovation system" or "system of innovation" was combined with the technological fields that were named most in the literature search in section 4.2[6]. Table 3 summarizes the use of these keywords in paper abstracts.

Table 3: Appearance of keywords in energy TIS publications

Technology	Keywords	Papers
Photovoltaics	PV, photovoltaic*	15
Wind power	wind, wind power	32
Biofuel	biofuel*, bioethanol	22
Biogas	Biogas	8
Hydrogen, fuel cells	fuel cell, hydrogen	17
CCS	CCS, carbon capture and storage	9
Combined heat and power	micro-CHP, CHP, combined heat and power	7
Electricity system, smart grid	smart grid, electricity system, energy system	25
Renewable energy, sustainable energy	sustainable energy, renewable energy, bioenergy, low carbon	46
Hydropower	hydro, hydro power	3
Nuclear power	Nuclear	8
Coal power	coal, coal power	10
Gas power	Natural gas, gas power	7
Total, duplicates removed		77

The results for each of these empirical fields were captured in a separate database and then combined to one single list, deleting all duplicates. With this approach, the retrieved database now contains 18 of the 22 key conceptual papers as well as a comprehensive set of closely related papers from other research communities.

The list of thematic clusters from the preceding section was accordingly used for categorizing the papers in this extended database. 62 of the total 77 publications could be allocated to one of these clusters (see table 4)

6 (TITLE-ABS-KEY("innovation system" OR "system of innovation") AND ("keyword X" OR "keyword Y" OR "keyword Z") AND (PUBYEAR = 2010 OR PUBYEAR = 2011) AND SRCTYPE(j)); Keywords summarized in Table X.

Table 4: Thematic clusters in recent energy TIS research

Thematic cluster	Number of publications
unclear	15
Functional approach to TIS	14
Considering contexts more explicitly	12
Policy implications / TIS governance	11
Application to other literatures	8
Geography of TIS	7
Actor strategies	6
Methodological issues	4
Total	77

The list of thematic clusters in this triangulated database had to be extended by two categories: Geography of TIS and methodological contributions. 7 papers take an explicit geographic perspective on innovation systems, mainly focusing on regional innovation systems and their connection to higher level system structures. As stated before, this list could additionally be extended by 3 papers from the conceptual core of TIS research. In addition, 4 papers exclusively discuss methodological approaches for innovation system analysis, namely foresight, modeling, system analysis and technology assessment.

A more detailed overview of each of the thematic clusters can now be provided:

- Policy / governance of TIS: Publications that use an innovation system approach to formulate or evaluate technology specific policies are most plentiful in the literature. There are only few additional contributions which discuss governance of TIS in the extended database.
- Considering contexts more explicitly: Here, Mostafavi et al. (2011) add an interesting general conceptual idea by arguing that innovation systems should be understood in a "system of systems" perspective. Three additional studies further concern the influence of context factors on TIS. They try to discuss TIS context either from a NIS or innovation network perspective, but do so in ways which are quite remote from TIS research. Finally, 6 additional papers discuss the relations between different IS concepts, relying on either SIS, RIS or NIS approaches. However, except for Coenen and Lopez (2010), none of them make explicit reference to TIS.
- Actor strategies: This thematic cluster is not covered by a lot of literature in the wider context of energy TIS studies. 3 of the 6 additional papers in this field are based on the management literature, the rest applies a transition, economics or NIS perspective.
- Application of the functional approach: In total, 7 studies discuss processes in specific TIS functions in more detail. 3 additional papers focus on knowledge creation and diffusion, whereas one paper by De Souza and Hasenclever (2011) looks at the standardization process which is related to the "guidance of the search" function. Application of the functional approach to specific fields of technology appears to be the dominant focus in the 7 papers in this thematic cluster.
- Application of TIS to other literature: Two papers use innovation system approaches to improve conceptualizations in other strands of literature. In addition to Binz et al. (2011), also Fu and Zhang (2011) apply an IS perspective to assess leapfrogging potentials in Indian and Chinese PV

industries. Finally, 6 papers combine a TIS perspective with transition theories. Three papers use TIS as a tool to assess niche processes in an MLP perspective, whereas the other 3 papers contain general reviews on how to fruitfully combine these two perspectives.

Apart from thematic clusters, the retrieved literature database revealed the following general features of energy TIS literature:

- About 70% of the empirical studies are based on single case studies. 20% compare different cases and about 10% are conceptual discussions based on literature reviews.
- An interesting and growing stream of literature focuses on the way policy influences TIS evolution by taking up political science or governance perspectives. Featured topics cover public-private partnerships, triple helix interaction, as well as planning processes, especially in urban contexts.
- Application of the context is expanding geographically: There is a growing stream of articles that applies TIS to developing and newly industrializing countries to assess their catching-up strategies or to discuss development issues. Besides the usual European countries, especially Brazil, China (also Taiwan) and increasingly the US are increasingly used for empirical studies (see table 5). Brazilian authors deserve special mention here for making conceptual contributions to the energy TIS's core agenda (e.g. Dantas, 2011; Pellegrin, et al. 2010; Huertas et al. 2010)

Table 5: Geographic focus of energy TIS studies

Country focus in case studies	Number of papers
Diverse	14
None	12
China	7
Brazil	7
UK	6
Unclear	5
Taiwan	3
Germany	3
USA	3
Netherlands	3
Western Europe	4
Eastern Europe	3
Asia	3
Others (Morocco, Argentina, Tanzania, Canada)	4
Total	77

- Finally, 5 journals stand out as the most popular outlets for energy TIS research: Energy Policy, Research Policy, Technology Analysis and Management, Technological Forecasting and Social Change and the International Journal of Technology and Globalisation (see Table 6)

Table 6: Outlets of energy TIS research

Journal	Number of papers
Energy Policy	8
Research Policy	5
Technology Analysis and Strategic Management	5
Technological Forecasting and Social Change	4
International Journal of Technology and Globalisation	4
Industry and Innovation	2
Renewable Energy	2
Journal of Technology Management and Innovation	2
Industrial and Corporate Change	2
Environmental Innovation and Societal Transitions	2
Agricultural Systems	2
Others	39
Total	77

4.4 Discussion of most recent trends in energy TIS research

Energy innovation systems research evolves around a relatively small core of conceptual contributions, which are provided mainly by research groups in Sweden (Chalmers University), the Netherlands (Utrecht University), Switzerland (Eawag) and the UK (e.g. SPRU, University of Leeds). Publications in the wider context are relatively plentiful and even though most of them are not directly related to TIS there appears to by a considerable potential of cross-fertilization from political sciences, management studies, economic geography and especially from plentiful publications on related innovation system concepts. Referring back to the research agenda sketched in section 3, the thematic clusters revealed in the review of recent literature show that the agenda dimensions can be extended mainly in 3 dimensions: 1) A growing body of literature tries to further conceptualize the processes that work inside specific functions. This approach arguably holds a high potential for future conceptual clarifications that go beyond the general open questions with the functional approach as discussed in section 3. So far, only knowledge creation and market formation are covered by this new line of research, extending this approach to the other TIS functions is thus encouraged. 2) Another emerging stream of literature which was not referred to in section 3 is the governance of TIS, which also holds promising potential for conceptual clarifications. 3) Increasing activity appeared in studies on geographic dimensions of TIS (mainly at a regional or urban scale) and application of the concept is diffusing strongly to newly industrializing countries. Finally, institutional analysis of TIS was mentioned in section 3 as an important agenda topic in TIS research. The literature analysis did however not identify a lot (if any) attention to this topic. Given the interesting conceptual input that institutional perspective could provide, future research in this field should be encouraged.

5 Conclusions and outlook

The aim of this literature review was to provide an overview of current trends and challenges in energy related innovation systems research by elaborating on major conceptual, methodological and empirical developments in the field in order to identifying promising future research lines. We have seen that energy innovation is a vibrant field of application for innovation system concepts. So far, the field seems to be much more strongly developed in the TIS tradition than in the others. However, NIS, RIS and SIS scholars are increasingly discovering the energy sectors as legitimate and productive application fields.

As the different innovation system concepts share a number of similarities and can be traced back to the same foundational concepts, it seems worthwhile to analyze in how far an integrated "energy innovation systems" approach could be formulated (Coenen and Diaz-Lopez, 2010; Weber and Rohracher 2012). We see a high added value in such an endeavor defining a potentially productive research field to which all sorts of innovation system scholars could contribute. Given the very unbalanced development stage of the different approaches, we proposed to elaborate an inroad into this upcoming field from the point of view of the TIS research community. The research lines that were identified in section 3 delimit a broad field for future research activities that would encompass and invite also scholars rooted in different traditions.

For instance there is an increasing interest in conducting comparative analyses of innovation system development in different national contexts (see van Alphen et al. 2010; Marinova and Balaguer 2009). TIS scholars are likely to gain substantially by considering approaches rooted in the NIS or RIS traditions. The latter approaches are likely to emphasize technology and sector spanning interdependencies in specific spaces (countries, regions) that a single-technology approach is likely to oversee (see for instance Kubeczko et al. 2006). Related to this we have to acknowledge that energy innovations increasingly take place in different countries across the globe. For instance emerging economies like, China, Brazil or India have become very important players in the field of energy innovation and cleantech industry formation. This trend is likely to continue and expand to other countries. Concepts have therefore to identify the emerging (multi-scalar) global structure of innovation systems which is influenced by several national technology policy strategies concurrently (Binz et al. 2012).

Regarding the transition problem, i.e. the longer term prospects of whole energy sectors in which emerging renewable technologies gain more and more prominence, energy innovation systems research should more explicitly focus on incumbent sector players and how they interact and interfere with emerging technologies (e.g. Erlinghagen and Markard, 2012). This requires more attention to regulatory incentive schemes and their influence on the prevailing innovation management cultures in the energy sectors (as described by Rogge and Hoffman 2010; Markard and Truffer 2006; or Cheon and Urpelainen 2012). Ultimately, what is at stake is an explicit model of sector transformation (similar to the transitions concept in the MLP tradition) that goes beyond a simple substitution of old technologies by new ones (cf. section 3 and Weber and Rohracher, 2012).

A third major line of future research relates to the interconnection of energy innovation systems research with management studies in order to better understand the role of (public and private) firms in the dynamics of emerging technological fields. We expect that the strategies and resources of organizational actors have a significant influence on how innovation systems develop and perform (Markard and Truffer 2008a; Provance et al. 2011). Recent contributions have also shown that firms and inter-firm networks can play an important role in creating collective resources at the innovation system level, thus contributing to innovation system building (Musiolik and Markard, 2011; Musiolik et al. 2012). This will open up new avenues to bring lessons from energy innovation research also to the attention of decision makers in industry and government (Farla et al., 2012).

Finally, we see a definite need to further work on improving policy advice from energy innovation system research. This relates to all aspects of innovation systems development: Measuring performance, assessing the functions, identifying blocking mechanisms, positioning specific TIS within an industry life cycle, etc. Policy makers may be at the regional, national or international level (like the EU or the OECD) (Weber ad Rohracher 2012). In particular, these policies have to be positioned in an increasingly global context and therefore also considerations of international interdependencies have to be taken into account (Truffer, 2012).

Summarizing the evidence collected in this Radar paper, we may conclude on a very positive note: Energy innovation system research is an emerging field with high promises. There is an extensive literature on which research can build but also a large room for further development and application of the core concepts. We consider that this field is vibrant and evolving and therefore an updated assessment of the identified trends in this literature review promises to add considerable insight into this highly important field of research.

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The grassroots of sustainable transition

A generic approach to describe Local Energy Initiatives in the Northern Netherlands.

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1. Introduction: The problem of grassroots sustainability transition

There is growing realisation amongst local communities that the organizations and societies within which they live and work need to become more sustainable in order to secure their social, environmental and economic futures (Coyle 2011, Müller et al. 2011). The underlying motivations vary but are often traceable to an increased need for certainty or security. The search for solutions is in part practically orientated towards resilience to different forces of decline. Whilst sometimes manifested in individuals it is more often evident within local initiatives seeking common ground and related to perceived needs for local independence or increased self-determination (Musall & Kuik 2011, Seyfang & Haxeltine 2012).

In our project and in this paper, our focus is on local initiatives as opposed to developments at regional or strategic scales. In the Northern Netherlands such local initiatives are often comprised of village residents or more heterogeneous groups from the wider rural community, with local initiatives co-existent in urban areas and cities. Local initiatives may focus on different sustainability issues (or a combination of them), such as transportation, energy, water, natural environment, food production, solid waste or the local economy (Coyle, 2011). However, many of these local initiatives focus on energy issues and solutions, while they might expand their interests to other issues after a prolonged existence. Therefore, in this paper we refer to these local or communal activities as Local Energy Initiatives (LEI's) that are at the grassroots of sustainable transitions.

The problem at the heart of our research project is that local energy initiatives are struggling to realize their goals or are sometimes even struggling to survive. Several of the local energy initiatives that currently exist in the Northern Netherlands fall idle or are unsure of how to continue. This may be after a first and often successful project with solar energy stemming from the installation of photovoltaic (PV) panels. What seems to be lacking for these local energy initiatives is adequate perspective on what to do and how to develop in the long-run.

Our project sets out to assist Local Energy Initiatives (LEI's) by finding a program of action most suited to particular localities. In order to realize this, we need to formulate a generic structure of the process that each LEI goes through including the several instances for options or specific actions that they may choose to focus on. Our methodology is inherently multidisciplinary since it involves actor perspectives from engineering, energy infrastructure, local politics, commerce, environmental groups, citizens, local farmers, housing associations etc.

We are interested in how LEI's organize themselves and how they embark on their 'Local Energy Program of action'. The **main research question** of this paper is: How can we generically describe the process of transition in local energy initiatives in the northern Netherlands? We will answer this research question in three parts. First, based on two short case descriptions of existing LEI's in the Northern Netherlands we start to explore the individual local processes of organisation and action. Next, we will suggest a possible theoretical grounding for this process. Thirdly, based on the practical experiences learnt from several LEI's, we present a generic active approach to the way in which they may choose to organize themselves and their activities in the formulation of their own "Local Energy Plan of Action".

2. Two cases of existing LEI's in the Northern Netherlands

Local Energy Initiative 'Groenkerk' (www.groenkerk.nl)
The village of Oenkerk in the north of the Netherlands consists of 1768 inhabitants, and is located 13 kilometres north east of the Frisian capital city of Leeuwarden. In 2011 a group of 7 village inhabitants started a local sustainability initiative called 'Groenkerk'. A first meeting of a number of village inhabitants who share the same vision and drive has lead to a chain reaction and snowball effect. The local network has extended to include farmers, housings agencies, private homeowners, local entrepreneurs, and the local churches. Some of the individual qualities and backgrounds of the 7 initiators have been noteworthy for the success of the LEI: director of a local communication agency, regional government, and council member of local government. As the initiative progresses the right organizational form for realizing the projects still needs to be found. The goal of this LEI is to "make the world more sustainable, starting in Groenkerk". The LEI wants to generate "contagious examples for others being fellow neighbours, other generations, other villages, and the rest of the world." (www.groenkerk.nl). The future goals of Groenkerk for 2050 are to:

- Supply their own sustainable energy for houses and businesses
- Produce a considerable part of their food needs within the village area
- Minimize flows of waste
- Create a healthy living and working environment for all inhabitants
- Care for each other
- Organize sustainable transport for village inhabitants

The initiative is focussed on raising awareness that through bottom-up initiatives people are empowered to create a sustainable world. Through self-management of a community, people become increasingly empowered as citizens and less dependent on local or national governments. LEI Groenkerk has repeatedly received press coverage and various requests to share their knowledge with other LEI's. In 2011 a survey of local inhabitants was organized to assess community needs and support for the initiative. The assessment results showed that the inhabitants were supportive of green energy, experiencing few shortcomings in social cohesion, they had mixed opinions regarding organic food production and were generally actively supportive of the LEI. The LEI communicates extensively with the local inhabitants through information evenings, workshops about local sustainability, local energy gatherings, and a neighbours-for-sustainability day. The local municipality supports the initiative, which may be best exemplified by the realization of an Energy Information Desk (*energieloket*) located in a house that was previously vacant and for sale. Now the house is a "living lab" for the people where solutions regarding sustainable building, sustainable energy and energy use are presented. It is also, where state-of-the-art knowledge is exhibited and where (local) companies can inform people about their solutions and products.

The main projects so far include collective purchase of PV panels; an energy savings project focusing on insulation (both with the help of several local companies); contributing to local primary school education; and local support of inhabitants. The project 'Local Energy Ahead!' is a collaboration with the Frisian Environmental Federation (FMF - Friese Milieu Federatie) and within which the inhabitants of the village Oenkerk are planning to establish their own cooperative Energy Company.

Local Energy Initiative 'Hooghalen Duurzaam' (hooghalenduurzaam.nl)
The village of Hooghalen is located in the forests and heather fields of the province of Drenthe in the Northern Netherlands, and consists of approximately 900 residents and a further 1400 within its rural surroundings.

The LEI has been organized as a foundation with a board that consist of 7 members. The foundation has initiated several projects and task forces in the field of insulation, energy savings, PV panels, collective purchasing of energy, and collective production of green energy. For the coming period the LEI is preparing a communication plan to continue to inform the village inhabitants and to secure their future support.

The ambition of this LEI is to realise an energy neutral village by the year 2020. Practically, the current focus of this LEI is on energy reduction, as expressed in their statement: "It is expected that through a joint approach the accomplishment of the objectives will be accelerated, because knowledge and commitment in the village is bundled. Sustainability is not just energy but it includes several aspects such as waste recycling, sustainable mobility, lifestyle (consumer activity) and water. For the sake of the scope of this initiative we will primarily focus on the reduction of energy use. The other aspects will be dealt with at a later stage." Current activities are mainly individual at this moment. The consequence is that savings are achieved relatively slowly. Inhabitants need to reinvent the wheel for their own particular situation. For each house or business the solutions differ and that makes it difficult for the individual citizen to determine the best course of action. Lack of technical knowledge and the ability to draft good financial evaluations often result in "no action at all". Therefore, joining efforts and expertise is at the heart of this initiative, and should lead to an acceleration of the sustainability transition in Hooghalen. The residents of Hooghalen are sympathetic towards realizing a sustainable village community. The people perceive the initiative as an opportunity to increase the quality of life in the village, and it gives a boost to local employment and social cohesion. Local companies are intended to be involved in the projects initiated by this LEI, however exploration of new solutions that are not offered by these local companies will be sought in the external environment.

3. Theoretical background

The assertion that sustainability transition is often approached from the top-down is taken as the contextual starting point, focussing on international programs (such as the Kyoto protocol or Rio agreement), national policies, the importance of action by governments, the 'crucial' involvement of multinational energy and water companies and so forth. Whilst the global or top-down approach has led to some results and will eventually be necessary at all scales it must be accepted that its short to medium-term effectiveness in creating or enabling widespread transition within local communities appears to be limited (Bäckstrand 2006).

It is at this scale that the negative impacts of unsustainable trends are more immediately experienced and finding the most effective means of empowering local communities would currently seem to be of the utmost importance. The effectiveness of empowerment has been specifically researched in the context of sustainable environmental management in disparate case studies (Fraser et al 2006).

The potential of emerging local energy initiatives is crucial for both research and policy making (Hielscher 2011, Thøgersen 2005). They are seen as an important first step in active citizenship that can be promoted as a solution to shrinkage of public budgets (Hajer 2011, Hajer 2012). They are also a sign that society is changing under the influence of individualisation and digitalisation (Castells 1996). People expect and demand more influence as a result of increasing individualism (Bang & Sørensen 1999). Parallel to processes of government, governance processes are appearing (Bogason & Musso 2006). In governance processes diverse actors may form coalitions and partnerships – which may or may not include government - to realize public goals. The direct involvement of a government actor is thus no longer a necessity. In the government model, the role of citizens was limited to test policy and co-produce policy at special determined moments during the procedures. However, in governance processes, the openness in policy formulating has increased considerably and citizens are able to become involved in the processes as an equal actor. This leads to a networked society in which local organisation processes can be increasingly accommodated within the overall system.

The number of local renewable energy initiatives is increasing dramatically. To illustrate this: in the Netherlands there were about 50 of them in 2011, halfway through 2012 there were 300 and by the end of 2012 there were 1500 known initiatives and nascent initiatives[i] and their number is still growing rapidly. More initiatives in other EU member states can be found on the website of the European Rescoop project (www.rescoop.eu).

The current, apparent incapability of the international community to find a global solution to the need for sustainable development could be the motivation behind the emergent trend of localised initiatives. Reasons to start local initiatives are (Oostra & Jablonska 2013):

- concern about energy prices or exploitation costs dwellings in the future
- to improve the quality of the community
- to improve social cohesion (especially in areas with declining population)
- the urge to do something together
- a means to jointly save energy
- control over own energy supply
- concern about the environment
- dissatisfaction with large energy companies
- a group has more power than an individual and organizing the energy supply for a group can be more efficient.

Theory development around these local energy initiatives is still in its infancy. An overview of what is available has been made as part of the Rescoop project (Hielscher 2011).

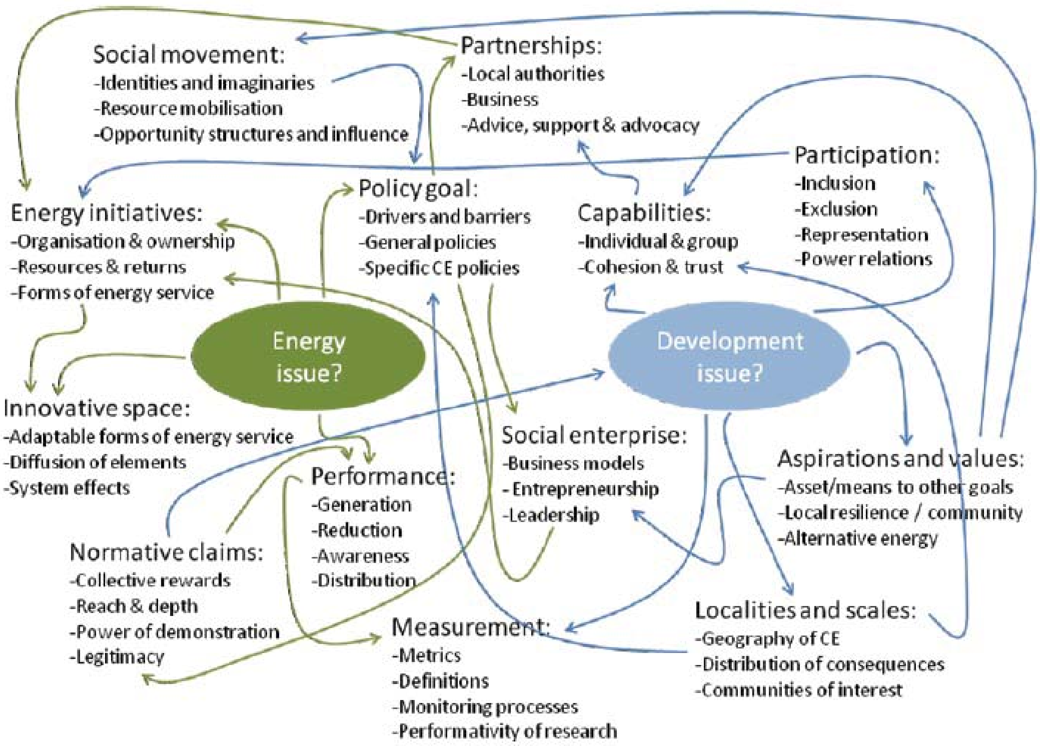

Figure 1. Overview of analytical themes in community energy research literature (Hielscher 2011)

Rifkin has described a proposal of how the future of our energy system could appear. Rifkin (2011) argues that conjoining internet communication technology and renewable energies is giving rise to a Third Industrial Revolution. The creation of a renewable energy regime, loaded by buildings, partially stored in the form of hydrogen, distributed via an energy internet - a smart *intergrid* - and connected to plug in zero emission transport, opens the door to a Third Industrial Revolution. The entire system will be interactive, integrated and seamless. This interconnectedness creates entirely new opportunities for cross-industry relationships. Furthermore, Rifkin argues, the Third Industrial Revolution brings with it a new era of “distributed capitalism” in which millions of existing and new businesses and homeowners become energy players (or prosumers?). Therefore it is important to know what homeowners, tenants and other end-users of energy need in order to become active players in our energy systems.

Instead of approaching sustainability transition from a top-down perspective and focussing on political and global actors, we propose a bottom-up perspective that starts with an analysis of the local network of actors in a community or village. This mapping out of the local network for sustainability transition is based on literature from science and technology studies, and more specifically actor network theory (ANT) (Latour 2005) and the social construction of technology (SCOT) approach (van der Blonk 2002, Pinch and Bijker 1987). Rooted in this strand of literature we propose to approach a Local Energy Initiative as a social process of a network of actors aiming to achieve a community purpose.

The actors who are involved in this social process are people who have invested time and energy together in order to reach a shared set of meanings attached to the local sustainability transition. Actors are active in local energy initiatives, aspiring to direct the energy network in their own community towards sustainable futures. However, the energy network is not easily changed; it may display ‘obduracy’ or resistance to change. The local energy initiatives also face the challenge of gaining permission to produce their own energy. For the past few decades all energy has been produced and governed in centralized systems. The transition to systems with many decentralized, sustainable producers, mostly feeding into the electricity grid, is meeting considerable political resistance in the Netherlands. Regulations and taxes have been used to discourage small producers in a number of ways; taxes for used energy are much higher for consumers and feed-in tariffs are lower or even non-existent. Local energy production seems to be hampered by juridical, financial and organizational obduracy. The centralized governance of energy infrastructure in the majority of situations sets the limits of the scope of action at local level. Identifying the strategies used by local energy initiatives to overcome, change or work-around the present centralized energy system is therefore essential. What is needed to make these LEI’s flourish?

The interpretations that people have, or the meanings that people hold within a certain LEI can be used to explain particular developmental paths (Pinch and Bijker 1987). Moreover, it might even be used to identity successful routes for future activities within the LEI or identify less promising routes. The multiple meanings that can be attached to the local sustainability transition can be radically different, which means that people within the LEI may have very different interpretations of what exactly is going on or for what purpose. Different actors may see different issues or problems for which they seek different types of solutions. A chosen course of action or an existing solar energy project within the LEI is thus open to be interpreted in different ways, and is itself also the result of an interpretation (a realized solution to a subjectively defined problem).

During the developmental process of a local sustainability transition the emergence of several frames of thinking may be discerned. A frame of thinking structures the interaction of the members of any relevant social group and it leads to the attribution of meanings. A frame of thinking is not a characteristic of an individual or a system, but built up when interaction around a local sustainability transition begins, and when these interactions move members of an emerging, relevant social group in the same direction. Frames of thinking “provide the goals, the ideas, and the tools needed for action. They guide thinking and interaction. A […] frame offers both the central problems and the related strategies for solving them […] Within a frame not everything is possible anymore (the structure and tradition aspect), but the remaining possibilities are relatively clearly and readily available to all members of the relevant social group (the actor and innovation aspect)” (Pinch and Bijker 1987, p191/2).

A frame of thinking thus predefines the meanings attached to the local sustainability transition and the interaction between the people within and between the actor groups. A frame of thinking may include (and thus predefine) elements like: the goals of the local sustainability transition, the key problems, the problem-solving strategies, the requirements to be met by problem solutions, current knowledge and theories, tacit knowledge, design methods and criteria, user’s practice, guiding examples of other local sustainability transitions or Local Energy Initiatives (van der Blonk 2002).

4. Sustainable community development program – a generic approach to describe LEI's

The problem at the heart of our research project is that local energy initiatives are struggling to realize their goals or are sometimes even struggling to survive. What seems to be lacking for these local energy initiatives is adequate perspective on what to do and how to develop in the long-run. Based on the described theoretical background combined with practical experiences from several LEI's we will present a generic approach of how LEI's may choose to organize themselves and their activities in order to formulate their 'Local Energy Program of action'.

The Sustainable community development program consists of 4 groups of activities that are part of an effective route towards informed, collective decision making and creative discussion. The entire program is therefore a combination of information gathering, analysis, discussion, (en)visioning and scenario building in several incremental spheres of development. The prescribed order is not rigid and can be easily adapted. The omission of any part of the program would be inadvisable since the completeness of the entire process has been carefully thought through on the basis of experience.

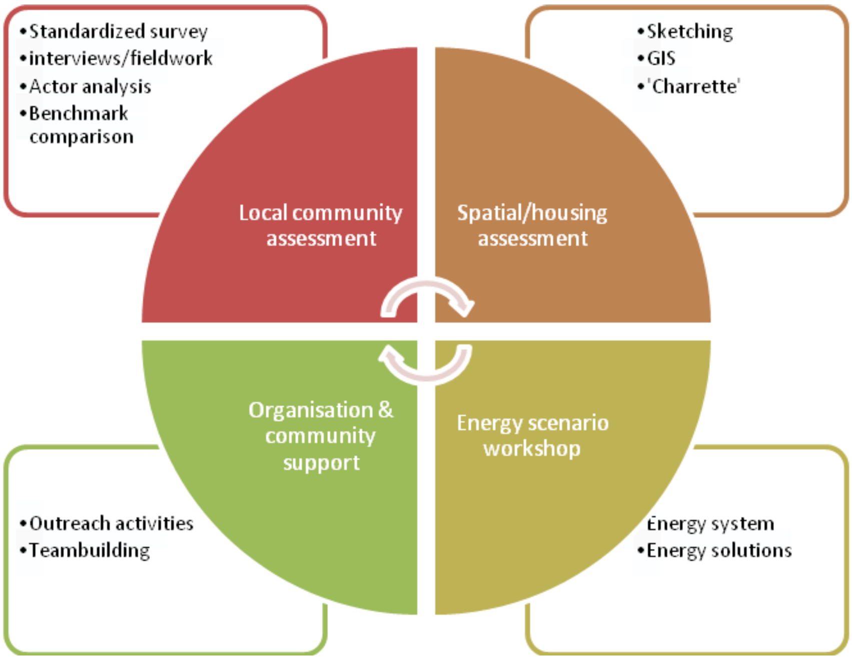

Figure 2. Sustainable community development program

Local community assessment (or village assessment)

For each local energy initiative we start with a structured description of the locality (such as a village, community or region) to determine the current situation and to compare the current situation of the locality to other localities (benchmarking). During this stage of assessment we have the following tools available:

- Standardized survey to map the local desires and existing support (the survey is conducted in cooperation with the LEI)
- The survey maybe complemented by a number of unstructured interviews, or other forms of descriptive data collection – depending on the specific locality.
- Analysis of local actors, interests and frames of thinking. Using a standardised tool (see figure 3 below) local actors, interests, and frames of thinking are observed and registered using the

tool. After registration, the data for the locality can be compared to other localities, in order to identify similarities and differences which likewise help to identify successful strategies and risks, further helping to identify potential issues to work on.

- Organizational model for the LEI
- When all descriptive data is collected we are able to compare the specifics of the locality under investigation to other localities that we have already studied and are included in our database of LEI's.

Actor/Social Group	Interests/power	Perceived problems	Proposed solutions	Meaning
Describes the persons or groups that are involved in the local sustainability transition	Describes the interests and power position of the actor or social group	Describes the way the social group perceives the central problem	Describes what the social group sees as desired solutions	Describes the meaning that the local sustainability transition holds for this actor/social group

Figure 3. Actors groups in local sustainability transition

Spatial/housing assessment (or analysis of current spatial situation)
In collaboration with the local energy initiative we organize a workshop that focuses on the landscape, land use and management, the historical spatial development, the natural environment (within and surrounding the locality), the built environment and the urban planning of the locality. What opportunities and threats do the workshop participants identify? The available activities for this stage are:

- Analysing (historical) maps of the locality and landscape
- Sketching the alternatives and possibilities
- Assessment of housing construction and insulation
- Using GIS touchscreen technology to visualize and disclose important spatial information
- Charette (creative "pressure cooker" discussion) workshop, including experts

Energy scenario workshop (or future energy potential)
In this subsequent step we co-organize a workshop with the LEI to present different energy scenarios that we have prepared based on the local community assessment and on the spatial/housing assessment. The involvement of experts in energy technology might be called upon. Besides the available technical energy solutions, the focus of the workshop will be on trying to achieve consensus within the LEI (and the local community) regarding choice for future actions or programs. What is the discernible energy potential? The available activities for this stage are:

- Systematic analysis of energy (and material-resource) flows
- Identifying the energy potential for the locality
- Assessment of energy production alternatives
- Formulating alternative (viable and feasible) proposals for the LEI
- Organizing a workshop to present the above

Organisation and Community support

We adjust to the cycle of meetings that are organized in the local initiative where the LEI is active. The available group of activities are:

- Manual/script for communication within a local community.
- Expertise and consultancy on organizational forms suitable for the LEI
- Organization of an event (research seminar, poster presentation or networking event) during the ESEW (European Sustainable Energy Week) in our own university venue.

5. Conclusion

In this paper we wanted to outline a generic approach to describe the process of grassroots sustainable transition for local energy initiatives in the northern Netherlands. It is significant that all initiatives start with a group of people, or a small network of actors, who want to develop and realize their local agenda of sustainability and sustainable energy aims. Village residents and locally involved citizens usually initiate these local energy initiatives, not government bodies or political movements (even though they may support the LEI). The actor network that is at the basis of the LEI may subsequently expand to include local businesses, farmers, housing agencies, and so on. With the growth of the network the number of ideas and projects increase as well, which may lead to a diffused and fragmented set of interests and activities by the LEI. In our generic approach we propose a complete assessment of the local actor network including all interests and ideas within the locality in order to generate a complete overview of the social context. Besides this, in our generic approach a further assessment will be generated regarding the spatial situation in the locality. A thorough analysis of the landscape and spatial surroundings of the village, combined with an analysis of the housing and built environment in the locality could reveal both possibilities and obstacles for the development of a local energy plan of action. During this spatial assessment phase, local knowledge might be combined with external expertise, which further expands the network of actors, interests and ideas. The social as well as the spatial assessment is necessary to identify the energy potential for the locality. This potential might be identified by the actors involved in the LEI themselves, for example through workshops, however, the LEI may also decide to use external expertise to investigate the full energy potential. A fourth and last part of the generic approach to grassroots sustainable transitions is the organization of the local network and its activities and to find support within the locality and the actor network of the LEI. Communication plays an important role at this stage and affects the foundation and form, underlying principles, scope, early agreements and establishment of objectives. All of these aspects could be determining factors, not only in the LEI's ability to find support and funding but also in the longevity and ultimate success of the transition towards a sustainable local community.

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[i] as presented at Hier Opgewekt, Amersfoort, 15 November 2012. Dutch LEI’s can be found via www.hieropgewekt.nl/initiatieven.

Submission: #272

Title: **A Second Wind? Comparing UK and Dutch Offshore Wind Developments**

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Keywords

offshore wind energy; sustainability transitions; empowering; fit-and-conform; stretch-and transform

Abstract

In various countries bordering the North Sea, offshore wind power has been positioned as a promising niche innovation that could play a major role in moving towards more sustainable energy systems. Although offshore wind deployment has taken off in recent years, it varies widely across European nations. The stark contrast between the recent boom in the UK versus a stagnation in The Netherlands leads us to ask: *What explains the difference in recent offshore wind deployment between the UK and The Netherlands?* To answer this question, we review relevant sustainability transitions literature and conclude that the scaling-up of niche innovations has so far remained somewhat of a 'black box'. Building on a recent theoretical contribution by Smith and Raven (2011) which argues for an analysis of the shielding, nurturing and empowering of low-carbon innovations, we articulate an analytical framework which distinguishes between *fit-and-conform* and *stretch-and-transform empowering* strategies. In line with Smith and Raven (2012), our analysis focuses specifically on actor networks and the narratives they create and use, which signals a departure from the more evolutionary representations of niche development.

Based on desk research drawing on sources such as existing academic work, histories of renewable energy sources, grey literature, trade press, stakeholder and government reports and news articles, we

create a chronology of key events in offshore wind developments in the UK and the Netherlands in the past decade. Subsequently, based on semi-structured expert- and key informant interviews, we apply our analytical framework and present a cross-national analysis. We found that in The Netherlands, empowering has alternated between the two strategies over the period under study, but in recent years 'stretch and transform' has taken a back seat to a 'fit-and-conform' strategy which focuses on realizing cost reduction though supporting innovation before supporting roll-out. Conversely, in the UK, 'stretch-and-transform' has been quite successful, with environmental values having been institutionalized in the form of the Renewables Obligation and offshore wind having become emblematic of sustainable energy production.

We conclude that because the narratives mobilized for the two strategies are quite similar between cases, in terms of the framework which focuses on actor networks and narratives an explanation must lie with the actors *behind* these narratives. We argue that the UK's relative success in stretch-and-transform empowering is at least partly the result of the presence of a system builder: an institutional actor which is financially and politically powerful enough to create conditions for large-scale roll-out to occur. Yet we also conclude that the framework fails to capture other explanatory factors, such as how competing issues on the policy agenda, and different institutional settings, can shape the possibilities for empowering work. Lastly, we engage with the debate around the national focus of many transition studies by showing that a conceptualization of protective space as being bounded in particular national jurisdictions can still be valid: despite the highly international nature of the offshore wind sector, attempts by multi-national companies active across different jurisdictions to empower niche up-scaling led to different outcomes in different countries.

1. Introduction

The development and deployment of renewable energy technologies is seen as key to tackling climate change (IEA 2011; IPCC 2011). Since many renewable energy technologies are not (yet) competitive with incumbent fossil fuel technologies in most contexts, public sector investment in research, development and demonstration (RD&D) as well as public policy incentives for the deployment of renewable energy technologies continue to play a major role for renewable energy technologies worldwide (Klaassen, Miketa et al. 2005; Sagar and van der Zwaan 2006; McDowall, Ekins et al. 2013). One technology attracting this kind of support is offshore wind (OSW). Historically, the deployment of wind turbines has focused on onshore developments, but several countries now pin significant expectations on moving offshore to exploit even greater wind resources (Esteban, Diez et al. 2011).

Especially in various countries bordering the North Sea, offshore wind power has been positioned as a promising renewable energy resource that could play a major role in moving towards more sustainable energy systems. For example the European Wind Energy Association (EWEA) argues 150 GW of offshore wind capacity could be realised by 2030, potentially providing 14% of the EU's 2030 electricity demand (EWEA 2011). By the end of 2012, total installed capacity by European countries represented over 95% of the worldwide installed capacity: well over 4,000 MW was operational (mostly in the North Sea), compared to just under 100 MW in 2001 (source: OSW farm database, www.lorc.dk). The deployment of offshore wind varies widely across European nations. As of late 2012, the top three contributers are the UK, Denmark and The Netherlands, who together are responsible for 88% of the total European installed capacity. The UK is the current market leader by far at 62%, whereas Denmark takes second place at some 20%, and The Netherlands is responsible for a further 6% (source: www.lorc.dk database). The capacity growth over time (see: Figure 1) reveals that these stark differences between the three nations were relatively minor around 2008, before which first-mover Denmark was market leader. Denmark was overtaken by the UK around 2009, and even though Denmark roughly doubled its capacity in 2010, it was further outpaced by the UK. In stark contrast, the third largest player The Netherlands had a capacity roughly comparable to that of Denmark and the UK around 2008, but deployment has stopped since.

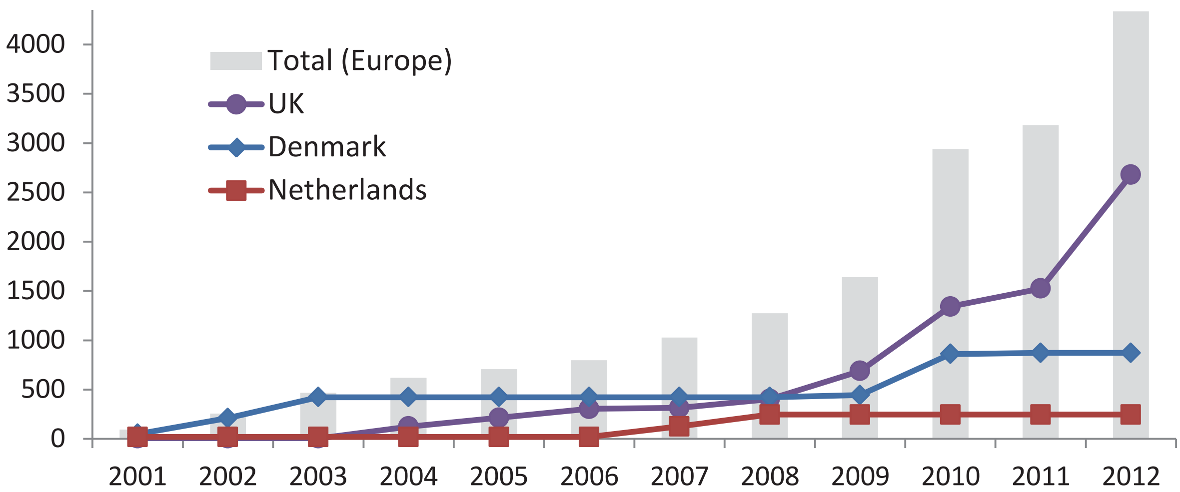

Figure 1: Cumulative offshore wind installed capacity (MW) for top three countries

This empirical observation, the stark contrast between the recent boom in the UK versus a stagnation in The Netherlands, not only suggests any European (or North Sea) innovation system is operating highly unevenly, but also leads us to our research question:

What explains the difference in recent offshore wind deployment between the UK and The Netherlands?

Explaining this contrast is particularly interesting given the fact that both countries have substantial offshore wind resource potential in adjacent exclusive economic zones in the North Sea; that both countries'governments have publicly announced their desire to be be a global leader in offshore wind;

and that some of the large and powerful industrial players involved in both countries' OSW deployment are identical (e.g. Shell, Siemens, Vestas, Fluor or Nuon).

The remainder of the paper is structured as follows: Section 2 will review the existing sustainability transitions literature relevant for addressing our question. This literature is a relevant starting point, because it has been demonstrated to be useful in explaining similarities and differences in emergence of and transformations in national energy systems in the past (cf. Bergek and Jacobsson, 2003; Geels and Raven, 2010). Section 3 will introduce our analytical framework, and our methodology. Section 4 will provide a timetable of key events in offshore wind developments in the UK and the Netherlands in the past decade. Section 5 presents a cross-national analysis of these developments based on our analytical framework, and section 6 concludes.

2. Literature review

In the sustainability transitions literature (and innovation studies literatures more generally), *onshore* wind power has been extensively analyzed (Jorgensen and Karnoe 1995; Gross 2004; Kamp, Smits et al. 2004; Klaassen, Miketa et al. 2005; Agterbosch, Glasbergen et al. 2007; Breukers and Wolsink 2007a; Bergek, Jacobsson et al. 2008; Kamp 2008). Its offshore counterpart has so far received less attention in these fields. A few authors have focussed on the *consequences* of the 'move offshore', e.g. for ownership and organizational structures in the wind power sector (Markard and Petersen 2009), while others have recently adoped a European perspective on offshore wind development. Such studies have therefore explicitly or implicitly included Dutch and British developments in this area as part of a European offshore wind innovation system (e.g. Jacobbson and Karltorp (2012); Luo et al (2012); Wieczorek et al. (2012)). This Europeal level of analysis is typically (and justifyably) legitimized by pointing to the internationally interconnected nature of the offshore wind sector. For example, Luo *et al.* (2012) assess the current state of the offshore wind innovation system and argue that, on a European level, the innovation system functions reasonly well at the moment: system functions that are lacking in one nation state, are 'compensated' by others. From this perspective, then, an answer to our research question into the difference between Dutch and British offshore wind deployment, would involve pointing to those innovation system functions which in The Netherlands perform subpar compared to the UK: search guidance (e.g. government resolve) and market formation (e.g. supporting incentives to create niche markets).

Yet this functional diagnosis provides only a partial answer: it does not explain how differences on these arguably important dimensions *came to be*. Our own empirical studies indeed support the existence of differences between national jurisdictions on these dimensions: the British government indeed views offshore wind energy as more of a priority compared to the Dutch government, and in the UK offshore wind is currently subsidized (through Renewable Obligation Certificates) (see e.g. Wood and Dow 2011) whereas in The Netherlands, it is not. But such observations are snapshots in time: the differences have histories. We are aware of the strong impact that (country-specific) policy instruments might have on the development of offshore wind technology (indeed the influence of state jurisdictions is part of the rationale for a cross-national comparison). But simply pointing to these as an explanation in our view obscures the processes through which such instruments came to be (i.e. their politics), and how these instruments shape the activities of offshore wind actors in both countries.

In their assessment of the offshore wind innovation system, Luo et al. (2012) further argue that “[n]ew technologies, sustainable in particular, being often far from optimised, frequently have to compete with very efficient matured and cheaper incumbents solutions. They need protected space to develop” (Luo et al, p. 59). We argee with this. Even though installed capacity has increased dramatically over the past decade, offshore wind is one of the more technologically challenging and expensive renewable energy alternatives and still very much remains a niche technology: currently, offshore wind power provides less than half a percent of European electricity consumption. The technical challenges are varied and include manufacturing suitable and reliable turbines for (and installing them in) harsh offshore environments, creating reliable foundations for increasingly deep waters, and developing high voltage direct current transmission systems to connect large offshore wind parks to onshore grids. These challenges render it relatively expensive: the International Energy Agency IEA estimates the costs for offshore wind to be between 140-300 USD/MWh, compared to 50-140 USD/MWh for onshore wind (IEA 2012). Indeed, offshore wind currently still receives major public financial support and other forms of ‘protections’ against mainstream ‘selection pressures’ such as price, efficiency, and infrastructural requirements. In the sustainability transitions literature, a conceptual perspective has been developed which specifically analyses such protections and the resulting protective spaces for sustainable technologies, which it refers to as ‘niches’. Strategic niche management (SNM) focusses analytical attention on the organization of learning processes, the articulation of expectations, and the formation of supportive networks of actors (Kemp, Schot et al. 1998; Verbong, Geels et al. 2008). So, from an SNM perspective, a working hypothesis regarding our research question would be that in the UK, offshore wind actor networks are broader and more resource-full, expectations are more ambitious and shared to a higher degree, and that learning processes are more reflexive and better organized. Yet, as was the case for the aforementioned functional (TIS) approach, such an explanation does not go into the necessary question of how this protective space came to be. In general, despite early claims of the importance of niche *creation* in transition processes (Kemp, Schot et al. 1998), SNM studies tend to take the existence of the protective spaces for granted.

Recently, Smith and Raven (2012) have addressed this issue by introducing an analytical framework based on *shielding*, *nurturing* and *empowering* processes. *Shielding* relates to the work that innovation advocates do towards creating a protective space that holds off mainstream selection pressures which, without such shielding, would 'select against' the sustainable technology. Shielding thus enables the second key process, *nurturing*, which is about the work that actors do to improve the shielded innovation's performance: work which is well-described in the strategic niche management literature. Finally, *empowering* relates to the strategic work that facilitates the wider upscaling of the niche. These three processes are acknowledged to be analytical abstractions (heuristics) that researchers superimpose on the observed work of innovation advocates, in an attempt to make sense of their actions. The practical, day-to-day and strategic work of these advocates, according to Smith and Raven (2012), consists of drawing on networks and creating narratives to enrol support for the niche technology.

This conceptual framework is thus rooted in strategic niche management, but goes beyond this literature by 'zooming out' to include attention for how its 'niches' are being constructed (shielding), and how they are scaled up (empowering). Smith and Raven argue that empowering is the least developed concept in the SNM literature. It relates to the question of how the process from the initial niche to a large-scale transformation can be accelerated (Coenen *et al.*, 2010). Upscaling, which is defined as "increasing the scale, scope and intensity of niche experiments by building a constituency behind a new (sustainable) technology, setting in motion interactive learning processes and institutional coordination and adaptation, which helps to create the necessary conditions for the successful diffusion and development of those technologies" (Coenen *et al.*, 2010: 296), is argued to be a critical challenge for strategic niche management (Coenen *et al.*, 2010; Geels *et al.*, 2008; Kemp *et al.*, 1998).

It is precisely in this area, upscaling, that we seek to make a contribution through a comparison of the UK and Dutch offshore wind developments focussing on the politics of empowerment processes. The large difference between the UK and The Netherlands in terms of installed capacity seems to indicate that attempts at upscaling the offshore wind niche have been more successful in the UK than in The Netherlands.[1] To explain this difference, we apply the analytical framework articulated by Smith and Raven (2012), focussing specifically on the empowering process. In the next section, we will elaborate on the concept of empowering.

[1] Of course, the absolute installed capacity difference between the UK and The Netherlands (roughly a factor 10 in 2012) is tempered by the countries' respective electricity consumption. Nevertheless, whereas offshore wind covered some 0.7% in The Netherlands in 2012 (CBS), it covered some 2.4% of total electricity consumption in the UK (DUKES). Hence, even corrected for electricity consumption, the offshore wind power's market share in the UK was still over 3.5 times larger.

3. Analytical framework and methodology

3.1 Framework

The socio-technical transitions literature recognizes two distinct upscaling trajectories: 'fit-and-conform', which is about making "niche innovations competitive within unchanged selection environments", and 'stretch-and-transform' which is about changing "mainstream selection environments in ways favourable to a path-breaking niche innovation" (Smith and Raven, 2012, p. 1025). Smith and Raven relate these upscaling trajectories to two corresponding types of (fit-and-conform and stretch-and-transform) empowering. Both types, they argue, result from "(…) sense-making advocates with uneven access to resources who try to influence powerful actors in different institutional positions and who often frame sustainability challenges and innovative solutions very differently" (p. 1031). These antagonisms, they claim, make empowering inherently political (Mouffe 1996).

Smith and Raven focus on narratives as a key political strategy for actor networks in arguing for (empowering) institutional reforms. This focus on actor networks and discourses signals a departure from the more evolutionary representations of protective space in previous SNM literature (Smith and Raven, 2012 p. 1031).

Actors and their networks are important in studying empowerment as it is actors who individually or collectively mobilise resources, learn, lobby policy makers etc. Transitions are necessarily multi-actor processes as no single actor unilaterally has the power or resources to bring about transitions (Grin, Rotmans et al. 2010). Therefore network governance (Rhodes 1997; Kooiman 2003) is central. Smith and Raven (2012) build on a familiar distinction between 'local' networks of socio-technical experimentation in specific project locations, and 'global' networks for converting that experience into more generic processes and norms (Law and Callon 1994; Geels and Raven 2006; Geels and Deuten 2006). To this, they add that "in the case of empowerment, global networks have an additional role to play if these processes are to persist, which is to secure the flow of resources that underpin these local-global processes. This requires commitments from actors in the wider social world. So in addition to inward-oriented network activities aimed at the practical development of a sociotechnical configuration, global networks are also engaged in outward-oriented activities of representing, promoting and enrolling support for that development" (Smith and Raven, 2012: 1031). They further acknowledge that the capacity to do so effectively differs between actors: "some are able to exercise greater influence owing to their resource attributes, experience, institutional positions, and connections with other influential actors" (Smith and Raven, 2012: 1031).

Narratives, Smith and Raven claim, are key political devices used by such global actor networks in their attempts to convince others and enable institutional reforms. Global actor networks strategically construct empowering narratives to either argue for institutional reforms which change the selection environment in favour of the niche innovation (stretch-and-transform empowering), or for support aimed at achieving competitiveness within unchanged selection environments (a fit-and-conform empowering).

Smith and Raven do not propose such narratives as sole explanatory variables for success and failure of niche development trajectories. Rather, they argue that they are useful for explaining (and perhaps even predicting) the socio-technical configurations that may emerge out of these trajectories (see also Smith, Kern et al. (in press)) on solar PV narratives in the UK and the resulting socio-technical configurations implied in those narratives). Still, the actor networks that are articulating and supporting these narratives do hold explanatory value for success and failure, given their different institutional positions and other available resources. Moreover, the two empowering strategies (fit-and-conform, stretch-and-transform) are supported by different narratives which imply different kinds of criteria to be fulfilled by the technology and its advocates. Indeed, when a narrative supporting a fit-and-conform strategy becomes dominant, technology assessment criteria will be directed towards low-cost, high-efficiency performance of the technology, while other criteria such as sustainability performance or democratic control of energy technologies or job creation are downplayed. This limits the potential application of technologies that are perceived by decision makers to perform poorly on the narrow cost-efficiency technology assessment criteria, which as we will argue in this paper, was the case for OSW in the Netherlands. Conversely, in the UK, narratives supporting a stretch-and-transform strategy became credible, which led to broader sets of criteria in institutional reforms of (renewable) energy policies enabling rapid deployment of OSW in the UK.

We will conduct a comparative analysis of offshore wind in the UK and The Netherlands, focussing on networks of actors, the narratives they employ, the contexts these draw on, and the outcomes (e.g. technology assessment criteria, supportive measures) they enable. Using Smith and Raven's 'empowering' perspective as our analytical framework will enable us to explain the observed difference in installed offshore wind capacity. The next section will lay out how we go about this.

3.2 Methodology

We use a *comparative idiographic* case study methodology (Tsoukas, 1989; Yin, 2009), because we are not interested in finding general laws that explain objective phenomena (cf. 'nomothetic case studies'), but in finding relevant patterns in the two cases' empowering processes in order to explain the observed differences. In other words: we do not aim to generalize from these samples to a population, but to a theory (Van de Ven, 2007) – in our case a better understanding of the politics of empowering the upscaling of low carbon innovation. Our method consisted of the following four steps:

Step 1. We compiled a timeline of key events around UK and Dutch offshore wind power developments. This timeline draws heavily on our national case histories of offshore wind developments (initially drafted as a basis for Kern, Smith et al. (in preparation) and Verhees, Raven et al. (in preparation)), which in turn were arrived at through desk research drawing on existing academic papers, histories of renewable energy sources, grey literature, trade press, stakeholder and government reports and news articles. The resulting abbreviated timeline focussing just on the last ten years is reproduced in Section 4. The national case histories cover the timeframe since the 1970s which is when there was initial interest in exploiting offshore wind in both countries, but for the purpose of this paper the focus is on the last decade which is when deployment really started to diverge.

Step 2. We did a series of *expert interviews* to understand the national case histories' underlying dynamics. The 20 experts were chosen for their knowledge of specific aspects of both countries' offshore wind developments: the (wind) energy sector (e.g. offshore construction, turbine manufacturing), policy developments, research undertaken at universities and by other actors, etc. (see: Appendix A). We used a *semi-structured interview* method, which enabled us to tailor the interviews to the interviewees and explore new themes emerging from their responses (Lindlof & Taylor, 2002). The interview guide's topics were *relevant actors*, *networks*, *narratives*, *events*, *projects* and *policies*. Key informants were asked to elaborate on their views on these topics.

Step 3. Based on the results from step 2, we transformed the national case histories into a comparative case study (Geels and Verhees 2011) of offshore wind empowering by applying our conceptual framework, using the indicators in Table 1 for investigating the two types of 'empowering work'. We then compared across the two cases, looking for salient differences. This comparative analysis is reported in Section 5.

Table 1: Indicators for empowering work. Adapted from: (Verhees, Raven et al. 2013)

Empowering strategy	**Description**	**Look for evidence of…**
Stretch-and-transform	Global actor networks work towards for changes in mainstream selection environments	…(attempts at) achieving institutional reforms …framing support as manifestation of sustainable values
Fit-and-conform	Global actor networks work towards niche competitiveness within unchanged selection environments	…arguing and promoting that innovation will be competitive under conventional criteria …arguing that no radical changes are required …framing shielding as temporary and primarily targeting performance improvement

Step 4. To triangulate (Yin, 1994) our assessment of the explanatory nature of these differences, we subsequently conducted one *key informant interview* with an actor who had professional experience in and extensive knowledge of offshore wind in both countries. For this key informant interview, we

used an *unstructured in-depth interview method* in which the interviewee was first asked to provide an explanation for the observed differences and was then invited to comment on our preliminary explanation of the development differences in the light of their own explanation. This provided a useful test of the validity of our findings.

4. A timeline of key events in UK and Dutch offshore wind developments

In Table 2, we provide a timeline of key events in the development of offshore wind in the UK and the Netherlands. This timeline is meant as an overview for readers unfamiliar with offshore wind developments in the respective countries, and provides a temporal context for the cross-case analysis which focuses specifically on empowering in section 5. For a more elaborate account of these developments in, respectively, the UK and The Netherlands, please see: Kern, Smith et al. (in preparation), Verhees, Raven et al. (in preparation).

Table 2: Chronology of key events for Dutch and British offshore wind deployment (2001-2012)

	United Kingdom	The Netherlands
2001	First UK offshore wind farm located in Blyth started operating (developed by consortium involving E.ON UK Renewables, Shell Renewables, Nuon UK, AMEC; capacity: 4MW) Crown Estate awards 13 leases for OSW farms (Round 1) Government announces a series of capital grants for OSW farms with consented projects receiving grants of up to £10m	Moratorium on new license applications for construction of OSW farms, pending design of new tender system Parliamentary consensus about spatial planning decision (PKB) for 1st (government-proposed, explicitly experimental) offshore farm (OWEZ) Environmental impact assessment for 2nd (commercial) offshore farm (Q7) accepted by government Government issues tender for concession to construct and operate OWEZ
2002	British Wind Energy Association (BWEA) organises first annual Offshore Wind Conferences	A Shell/Nuon consortium is awarded OWEZ concession Energy Report: Ministry of Economic Affairs (EZ) sets goal for 6 GW in 2020. Supported by NGOs
2003	Crown Estate announces a second round of OSW licenses located further out at sea with a capacity to host 6 GW of OSW by 2010 (Round 3)	Council of State overrules conservation society & coastal community residents' objections to PKB for OWEZ Council of State rejects proposal for concession system for licensing future farms (reason: insufficient substantiation of selected areas) Renewable production stimulation scheme (MEP) replaces failed demand-guided subsidy (REB)
2004	E.ON commissions its Scroby Sands 60MW OSW farm	Consortium We@Sea gets funding for research aimed at applying experiences with OWEZ to future farms OWEZ and Q7 are granted a 10-year-guaranteed kWh production subsidy through the MEP scheme

2005	Vattenfall commissions its Kentish Flats 90MW OSW farm	Moratorium on applications lifted: first-come first-served licencing procedure for Round 2 New moratorium due to unexpected high number of applications. MEP production subsidy nixed for OSW Central Planning Agency (CPB) concludes investing in OSW is not societally profitable in short term EZ now in favour of controlled, phased deployment of 6GW goal (no-regrets strategy) Construction of OWEZ begins
2006	Research Council funding for SUPERGEN Wind Energy Technologies Consortium made available (2006-2010 and 2010-2014; combined funding: £7.38)	Moratorium on applications for Round 2 licenses lifted OWEZ begins supplying electricity to the grid & construction of Q7 begins MEP subsidy scheme unexpectedly terminated
2007	UK government signs up to EU 20-20-20 targets which subsequently act as a strong driver for renewable energy policy	Department of Public Works (RWS) continues to evaluate licenses. Some controversies over rejections. Government announced new, capped, production subsidy scheme (SDE) to replace uncapped MEP
2008	Crown Estate launches the Round 3 licensing process by identifying nine strategic zones within and outside UK territorial waters for OSW development with a capacity of 25 GW Carbon Trust launches Offshore Wind Accelerator (2008-2014) providing funding for R&D and demonstration projects (£41.5M)	Government announces subsidies for Round 2 through SDE & promises to replace license system with concession system (appointing strategic areas) for Round 3 (aimed at realizing the 6 GW goal) Q7 begins supplying electricity to the grid (completing Round 1)
2009	Government introduces 'banding' of Renewables Obligation (RO), significantly increasing deployment incentives for OSW (from 1 to 1.5ROCs/MWh) UK Offshore Energy Strategic Environmental Assessment (SEA) identifies up to 33 GW of offshore wind capacity in UK waters Climate Change Act sets legally binding carbon emission reduction target of 80% by 2050 and establishes Climate Change Committee An EPSRC funded doctoral training Centre for wind energy research is established at the University of Stathclyde (£5.8m) The Energy Technology Institute launches an offshore wind programme worth £40m of funding, including for a test rig at NAREC DECC publishes an OSW demonstration call (£27m)	SDE tender process for Round 2 (950 MW) initiated for license holders OSW sector initiative FLOW established for R&D of far-shore OSW technologies Taskforce Offshore Wind Energy created by EZ to advise on optimal strategy for OSW development
2010	Inventive for OSF deployment revised (to 2ROCs/MWh) upwards given increasing costs of OSW Climate Change Committee suggests an 'important role' for OSW as part of the least cost path for decarbonizing the power sector Crown Estate announces the successful Round 3 developers and sets up a 'Offshore Wind Developers Forum'	SDE tender won by German Bard Gruppe for Gemini OSW farm (acquired by Dutch developer Typhoon in 2011) New Minister of EZ alters SDE: OSW is out. Stated reason: focus on renewables roll-out, for which OSW is currently too expensive New EZ policy line announced: government stimulation of bottom-up (industry) initiatives in 9 pre-defined sectors ('top sector policy')

2011	DECC publishes Renewable Energy Roadmap in which it expects OSW to reach a capacity of 18 GW by 2020 and over 40 GW is seen as possible by 2030 DECC sets up an 'Offshore Wind Cost Reduction Taskforce' to develop a credible strategy to reduce OSW costs to £100/MWh by 2020 DECC and Scottish government announce business investment grants for offshore wind manufacturing (£60m for England; £70m for Scotland) DECC and the Technology Strategy Board announce 'Offshore Wind Component Technologies Development and Demonstration Scheme' (£15m) Three proposed OSW projects in Scotland are cancelled due to local opposition	Unallocated budget from SDE tender awarded to Eneco's Q10 OSW farm proposal Energy Report (EZ) views OSW as long-term option: focus on stimulating innovation aimed at cost reduction 'Green Deal Offshore Wind' between wind sector representative NWEA and government OSW designated one of 7 'key areas' in Top Sector Energy At EWEA wind energy conference, Dutch OSW sector celebrates the 'birth of Dutch offshore wind'
2012	The government's Technology Innovation Needs Assessment concludes that "offshore wind is a commercially available, proven technology" Offshore Wind Developers Forum commits to sourcing 50% of OSW project content in the UK Technology Strategy Board sets up 'Offshore Renewable Energy Catapult' (£50m) ETI and EPSRC funded Industrial Doctorate Centre in Offshore Renewable Energy established at the University of Edinburgh (£6.5m) Siemens receives planning permission to build OSW manufacturing plant in Hull, and Gamesa signs a Memorandum of Understanding with Forth Ports to build a manufacturing facility	Offshore Wind Innovation Contract signed FLOW becomes organizing the Top Consortium for Knowledge and Innovation (TKI) for Top Sector Offshore Wind New government's coalition agreement continues recent offshore wind policy.

5. Empowering Dutch and British offshore wind: a cross-case analysis

This section presents the results of our cross-case analysis. In line with the conceptual framework discussed in section 3 we will first analyse the fit-and-conform and stretch-and-transform empowerment processes in both countries, focussing on which actors and which narratives played key roles. The analysis then focusses on salient differences between these, and examines to what extent they can explain the differing fortunes of offshore wind in the two countries over the last decade.

The overall finding from looking at the empowering processes in both countries is that while in the UK a growing coalition of influential actors was actively supporting offshore wind developments as being in line with their perceived interests, developments in the Netherlands were much more contentious with several policy U-turns, changing political coalitions, and competing advocacy networks. We will argue that despite early attempts at 'stretch-and-transform' empowering by a number of actors in the Dutch case, and the articulation of required institutional reforms in energy subsidy schemes and licensing procedures, decision makers in power eventually landed with a 'fit-and-conform' view of offshore wind. OSW became perceived as a long-term (albeit likely inevitable) option, which *first* needed cost reductions and efficiency improvements, before deployment would be financially and institutionally supported. In contrast, OSW advocates in the UK were able to simultaneously pursue both strategies successfully which resulted in the large difference in recent deployment in OSW.

5.1 'Fit-and-conform' empowering

In both countries, we found evidence of networks of actors trying to obtain support for the further development of OSW to enable learning (Junginger, Faaij et al. 2005) which would make the technology cost competitive in the future. For example in the UK, academics, technology developers as well as existing public sector bodies set up to provide innovation funding were pushing to channel resources into R&D to make offshore wind competitive with other electricity generation options. Several initiatives aimed at reducing the costs of OSW were funded including the Carbon Trust's OSW Accelerator, the Energy Technology Institute's OSW Programme, the Technology Strategy Board's Offshore Wind Component Technologies Development and Demonstration Scheme. Public funding for wind research remained low until the mid-2000s. Since then, as Halliday and Ruddell point out, "The volume of R&D in the UK is now rising, prompted by the drive for efficiency improvements and overall cost reduction" (2010: 2). Funding was not only provided for R&D but also a testing infrastructure for large turbine designs was put in place at NAREC with the help of public finds. In The Netherlands, the current policy paradigm concerning innovation (i.e. the Top Sector Policy) is perhaps even more explicitly geared towards realizing cost reductions which are seen as pivotal for roll-out. Agreements to this effect, such as the Offshore Wind Innovation Contract and the Green Deal Offshore Wind have been made between virtually all Dutch offshore wind sector actors and the government, which adopts a facilitating role (e.g. promising to remove regulatory barriers, and supporting and co-funding initiatives by market parties aimed at innovation for cost reduction). In both countries, it is relatively uncontested that offshore wind has potential, and that funding innovation geared towards cost reduction is relatively cheap compared to deployment subsidies.

There is also evidence that in both countries, support for offshore wind was framed as a temporary measure, which is targeted at improving performance. For example, OSW in the UK context was portrayed by government actors as generally being a "commercially available, proven technology" (LCICG 2012) which just needs temporary, targeted support to make it cost effective (at least compared to other low carbon technologies). In The Netherlands, the framing of such support as a temporary measure by both the government and market parties has been the subject of contestation in parliament in the mid-2000s, which resulted in a 'no-regrets', step-wise type approach to the implementation of the ultimate goal of 6000 MW which meant that the implementation could be stopped at any time, should the promised performance improvements *not* materialize.

Finally, we found evidence in both countries for claims that no radical changes to current systems are required for offshore wind to 'work'. In the UK case, several interviewees pointed to the shared sense developing across actors over time that in order to fit alongside conventional power stations and to be economical, offshore wind had to be bigger (interviewees 3; 5; 7; 8; 9; 10). To deliver on this expectation public research projects such as Supergen as well as industry R&D focussed on scaling up wind turbines to very large sizes (interviewee 7; 11). Technology experts expect the trend towards larger turbines to continue (interviewee 4; 5; 7; 13). Even as far back as in the 1980s some actors (e.g. the Central Electricity Generating Board) took some interest in developing ‘offshore wind power stations’ (interviewee 12). In The Netherlands, thinking has developed along similar lines. Dutch 1970s offshore wind studies spoke of ‘power plants’ in the North Sea (Van Staveren, 1974) based on very large (and highly speculative) 10 MW turbines, while in the mid-1980s, the Dutch contribution to an IEA-funded offshore wind research program consisted of a conceptual design for a gigawatt ‘offshore wind energy plant’ using 3-4.5 MW turbines. Since then, the logic of a concentration of multi-megawatt turbines organized in ‘parks’ or ‘farms’, dictated by the technical and economic challenges of offshore construction, has become the default standard in thinking about, and implementing, offshore wind. This contrasts with its onshore counterpart, where ever since the late 1970s the focus on large-scale centralized wind farms was criticized by e.g. the appropriate technology movement, who, under the maxim ‘small is beautiful’, favoured small-scale (kilowatt) decentralized wind energy (Verbong et al., 2002). Once the Dutch goal of implementing 6000 MW of offshore wind power came into focus, is was also argued that no substantial modifications to the Dutch electricity grid were required. For example in 2003, an ECN study concluded that extending the Dutch grid by constructing new offshore substations was unnecessary, as it would offer no economic advantages to connecting individual parks to the existing grid (Herman & Pierik, 2003), in much the same way as conventional power plants are. Similarly, the Ministry of EZ initiated ‘Connect 6000’ research project concluded in 2004 that ‘fitting’ offshore wind into the existing grid would not be prohibitively expensive: up to 3000 MW there would be no extra costs, and between 3000-6000 MW costs would be around 300 million EUR (Ummels et al., 2007). Such claims can clearly be interpreted as part of a ‘fit and conform’ strategy where the socio-technical configuration of OSW is aligned with the existing design of electricity systems (large scale, centralised generation).

5.2 ‘Stretch-and-transform’ empowering

The UK case study reveals evidence of a number of institutional reforms that were enacted to enable the scaling up of offshore wind as a sustainable energy option.

- The most important change to the selection environment is the Electricity Market Reform the UK government is currently undertaking. This represents a radical overhaul of the electricity markets rules in order to empower low carbon generation by introducing long-term feed-in tariffs for a number of low carbon electricity options including offshore wind. These so-called contracts-for-difference guarantee investors an above market price for the electricity generated for 20 years. In this way the electricity market rules institutionalise support for OSW upscaling.
- Another important example of empowering processes is the change of rules implemented under the EU Third Energy Package. This EU policy did not allow offshore wind developers to build

and operate transmission cables connecting the wind farm to the grid (because of the separation of generation and transmission for competition reasons). Several interviewees mentioned this rule as an obstacle to investment in offshore wind. Following pressure, Ofgem addressed this concern by changing the rules and allowing the 'generator-build option' (Crown Estate UK Offshore wind report 2011: 5). In the words of a government minister: 'we had to get Ofgem to stop being pedantically market driven' (cited in: Toke 2011: 528) which helped to address industry concerns (interviewee 6; 8; 12). This is a clear example of where rules were changed in order to empower offshore wind.

- A third example is a change in the planning rules for Round 3 projects in order to streamline the process. Special procedure were set up for big wind farms and offshore wind farms were also given precedence ahead of other considerations including the allocating of Natura 2000 conservation sites (Toke 2011: 528). This was following industry concerns that planning processes were cumbersome and were introducing delays (interviewee 3; 6; 8; 12).

The networks of advocates advocating these changes included the utility companies with an interest in offshore wind (like Centrica, Vattenfall, SSE, RWE, E.ON), specialised project developers (like Mainstream Renewable Power), potential investors, trade bodies like RenewablesUK, environmental groups such as Greenpeace, the Royal Society for the Protection of Birds, Friends of the Earth and the WWF (Toke 2011: 528) and the Crown Estate[2]. Offshore wind was presented as an important part of the solution to the problem of how to meet renewable energy and climate change mitigation targets, concerns about a pending 'energy gap' and simultaneously creating new manufacturing jobs in the UK in times of recession (Kern, Smith et al. in preparation). The analysis revealed that there has been an increasing formalisation of public-private networks with initiatives such as Offshore Wind Developers Forum (OSWDF) and DECC's Offshore Wind Cost Reduction Taskforce being set up. The Offshore Wind Developers forum is a network of developers trying to jointly discuss and solve problems facing the industry. It was set up by Crown Estate in 2010. A manager from a utility company sees the forum as very helpful in terms of 'having a united position as an industry' (interviewee 6). In addition, the Offshore Wind Cost Reduction Taskforce has been set up in 2011 to bring together government with important industry players to develop a credible strategy to reduce offshore wind costs to 100£/MWh by 2020 in responses to concerns about the high cost of OSW. These networks were again broadened by the recent interest of several turbine manufacturers to set up production facilities in the UK as well as financial investors increasingly finding the UK attractive because of the market potential (interviewee 1). Overall, the argument is that over time a coalition of powerful and resourceful actors emerged which boosted the credibility of and channelled resources

[2] The Crown Estate is a company set up by government to manage Crown owned land which includes almost all of the seabed of the UK outside of the 12mn zone. Its profits go back to the Treasury. Developers need a license to develop an offshore wind farm and have to pay a license fee for using the seabed to the Crown Estate.

into offshore wind. Formal networks centre around key public organisations as well as incumbent energy regime actors (including energy companies such as DONG and Statoil, several of the UK big six utilities and key established manufacturers such Siemens, Vestas, and Alstrom). Toke argues that the political strengths of the UK renewables lobby is now comparable to that in Germany since the 1990s as by and large it is the energy majors who are doing the investing (2011: 529).

In summary, in the UK, stretch-and-transform empowering has contributed to the deployment of offshore wind by helping to overcome some specific barriers but also by providing ‘political signposts’ that the government is serious about offshore wind and is willing to re-shape institutional frameworks in order to allow the continued growth of this niche and make it a central part of the future electricity portfolio. As a renewable energy developer company put it: “That’s made quite a difference I think just generally because it gives people more confidence in the higher risk development stage to invest. So planning reforms, electricity market reforms which have been much more heavily dominated towards offshore wind than ever before” (interviewee 8).

In contrast, ‘stretch and transform’ empowering was a much more contested affair in The Netherlands. This becomes evident in the licencing, subsidizing, and spatial planning of Dutch offshore wind:

- *Licencing.* In the early 2000s, the government had planned to draft policy for offshore wind based on experiences with the first, experimental, park (OWEZ). But when private developers (Nuon, E-connection, Evelop, Greenpeace) filed for applications to construct additional parks at a time when the government had not expected interest by the market, a moratorium was announced pending the design of a licencing system. This was to take the shape of a concession system (after Danish example), whereby strategic zones for OSW construction would be designated by the government, and interested parties would receive a concession. In such predefined zones, environmental criteria could be included, the various users of the North Sea could be consulted, and their interests could be weighed. A concession would be a requirement for filing for a licence to construct under the Law on Public Works (Wbr). Smaller developers argued against such a concession system, believing that it favoured ‘big players’ over newcomers (interviewee 22) and favoured handing out licenses under current legislation. Smaller developers argued that under the government’s proposed concession system, “[y]ou’ll only get a licence if you can demonstrate with certainly that you can build the park. This drives independent developers out of the market. Only big players like Shell and Nuon can give such guarantees” (Financieele Dagblad, 17 March 2004). Yet when the design for a concession system was complete, it was overruled by the Council of State on the grounds that the argumentation for the chosen zones was insufficient. Independent developers as well as Greenpeace argued that it would be a mistake to go back to the drawing board: the continued absence of a licence policy was scaring away potential developers and investors to e.g. the UK, and it would result in a stagnation of offshore wind deployment after the commissioning of the two 'Round 1' parks (Nieuwsblad Stromen, 4-2-2004; De Vries & Van Sambeek, 2004; Trouw 21-7-4). Several members of parliaments argued for moving quickly so as not to completely lose momentum and give market parties the chance to apply for licenses based on current policy instead (Nieuws Stromen, 22-7-2004, "Concessiestelsel voor wind op zee van de baan"). For example, Samsom (Labour, opposition) argued to "forget about the concession system, [because] on the basis of current legislation [meaning Wbr] it is already possible to hand out licences with which investors and developers can get to work immediately" (Verslag algemeen overleg, 15 juni 2004, 29575, nr. 3). When the government lifted the moratorium on notices of intent to construct offshore wind parks, it announced that licencing would take place on a first come first served (FCFS) basis instead of a concession system: whichever party managed to complete an application (which needed to include an environmental effect report) for a given location first, got the spot. This move towards a more 'fit-and-conform' strategy was criticized by those who argued that an FCFS process was only suitable for more mature and stable industries (Zeelenberg, 2006; COD, 2005). Ten joint environmental organizations argued that "(…) offshore wind is no business for the free market. Wind parks require financial support and careful special planning. This is a government's task: it should stimulate offshore wind in a predictable fashion and take charge of the locations of wind parks" (Stichting De Noordzee, 2005 p. 6). Dutch wind energy sector representative NWEA favoured an FCFS procedure for 'Round 2', but lobbied the government for a strategic location policy involving all potential stakeholders, using the British system as an example, for the future 'Round 3' (NWEA, 6 August 2008). In 2009, the government announced that it had now chosen for a concession system instead of licenses: it would appoint strategic areas, large enough in principle to accommodate 6000 MW, within which it could give exclusive permission to market parties to develop OSW parks and within which it could deny non-OSW projects. It could also deny applications to construct OSW parks outside these areas, which was meant to prevent conflicts with other North Sea users. Nevertheless, this movement back towards a more 'stretch and transform' strategy has not yet produced results, as Round 3 is expected to open in 2015 at the earliest.

- *Subsidies.* The Ministry of EZ's 2003 renewable energy production subsidy (MEP) was an attempt at a stretch-and-transform empowering of renewable energy sources, including offshore wind: it was an open-ended scheme that levelled the playing field by 'subsidizing away' the estimated production cost difference between various renewables and conventional electricity production. Subsidizing offshore wind through MEP was politically contested: economic liberal and conservative parties framed OSW as a 'hobby horse' for progressive and green parties, and dismissed it as 'running on subsidies instead of wind'. The unexpectedly high number of notices of intent for offshore wind park construction filed by market parties after the moratorium was lifted in early 2005 led to a new (temporary) moratorium and the cancellation of the (open-ended) production subsidy scheme for offshore wind. The Minister stated that costs would run out of control: it was too successful and therefore too expensive (http://www.energeia.nl 10 May 2005). The moratorium was lifted again in 2006, but after a few months the Minister unexpectedly terminated MEP altogether, arguing that The Netherlands were on course for realizing the '9% renewables in 2010' goal and so no further subsidy was needed. The government admitted that the subsidy scheme's design had been flawed: projects meeting the criteria could not be refused and were awarded a guaranteed production subsidy based on a price expectation. But because price levels fluctuated, costs increased dramatically and the budget was exceeded. With previous experience in mind, the MEP had been designed to prevent constant adjustments by the Lower House, which left nullification as the Ministry's only option to prevent further budget transgression (Köper, 2012). In its stead, the government now desired a new and less out-of-control subsidy scheme based on tenders and budgets per sector (Wind Service Holland, 31 August 2006). The NWEA called the government "unreliable" in response, blamed the Minister for not having consulted with the sector (Het Parool, 22 August 2006), and started lobbying for a redesigned MEP based on a feed-in-tariff (NWEA archive, 17 October 2006). In late 2007, the government announced a new, capped, production subsidy system (SDE) which, it promised, would also be used also to stimulate offshore wind deployment: it committed to 450 MW of offshore capacity in Round 2, to be allocated through an SDE tender. The budget was increased to 950 MW in 2009 as part of an economic stimulus package: the remainder of the 6000 MW goal would be subsidized in a step-wise fashion through SDE. Yet in 2010, the Minister drastically altered the SDE production subsidy scheme: in the resulting SDE+ scheme, instead of differentiated cost-of-production estimates for different renewable sources, a single (and much lower) amount was set for all renewables, and subsidies for offshore wind were terminated altogether. The Minister stated that "[w]here the previous SDE focused on two goals, roll-out and innovation, I want to focus SDE+ on an efficient roll-out to make headway in achieving the target of 14% renewable electricity in 2020" (Energeia, 30 November 2010). Offshore wind, according to the Minister, had no place in this: it was too expensive for roll-out, and the required innovations to achieve this, would no longer be subsidized through SDE(+).

- *Spatial planning.* Spatial planning in the Dutch EEZ has been a contested affair. The existing applicable regulatory frameworks, Integraal Beheerplan Noordzee (2005) and Nota Ruimte (2006), were based on individual consideration of market initiatives (Planbuerau voor de Leefomgeving, 2008). But in 2008, conflicts between different users of the North Sea (e.g. around the required safety zone around wind farms) and worries about the environmental impact of the increased use of the North Sea led to calls for a governmental zoning plan (Rijksbestemmingsplan) for the Dutch EEZ under the new Law on Spatial Planning 'Wro' (e.g. Motie-Polderman, Tweede Kamer 2008/2009 29 675 nr. 54). *Onshore* governmental zoning plans are instruments for guiding spatial development based on broader spatial considerations: on appointed locations, some activities are permitted, whereas others are excluded, and it was argued that for offshore locations, they should to the same. The government rejected the proposal, arguing that the current instruments, although not specifically designed for that purpose, provided sufficient flexibility for guiding offshore developments (Tweede Kamer, 2010/2011 29 675 nr. 118) while the new National Water Plan (which for North Sea policy replaced the Nota Ruimte) would provide a sufficient framework for assessing (the broader implications of) individual initiatives (De Gier et al. 2011).

In summary, in The Netherlands, various attempts were made at 'stretch and transform' institutional reforms to enable the scaling up of offshore wind as a sustainable energy option, but these attempts 'failed' to the extent that they developed into and/or were replaced by more 'fit and conform'-oriented institutions.

5.3 Key differences between the UK and NL

One key difference between the developments in the UK and the Netherlands is the prominence of climate change and renewable energy goals within energy policy making in the UK, which provided a favourable context for empowering activities of offshore wind advocates. Especially in the most recent period, the 2009 Climate Change Act has institutionalised very ambitious climate change targets in law (80% reduction by 2050) and climate change has also been institutionalised within a combined Department for Energy and Climate Change (DECC), arguably giving this consideration more weight within energy policy compared to the previous institutional set up. This contrasts with what in the Netherlands has been called a "low sense of urgency" about climate change by the government (Nieuwsblad Stromen, 4/2/04; Trouw, 21-7-04) which provided a much more 'unfriendly' context for OSW advocacy. Indeed, for the center-right coalition (CDA/VVD/LPF) that had come to power in mid-2002 integration, terrorism and safety were dominant themes, and renewable energy subsidies were cut down severely (Köper, 2012). In response, three existing wind energy branch organizations (Dutch Wind Energy Association NEWIN, consisting of individuals and organizations in the wind energy sector, FME Wind Energy Group, consisting of manufacturers and subcontractors, and association of independent wind turbine operators PAWEX) joined forces in a network organization called De Windkoepel to lobby for policy change, though attention was mostly focused on onshore wind in those days (Agterbosch, 2006). In spite of this and similar efforts, in the subsequent coalition (CDA/VVD/D66) that came to power in 2003, climate wasn't a key issue, either: the Minister of Housing, Spatial planning and the Environment (VROM) delegated climate policy completely to her Secretary of State who failed to re-prioritize it, while the Ministry of Economic Affairs (responsible for energy policy) was primarily focused on the full liberalization of the energy market in 2004 and on redesigning the failed sustainable energy demand subsidy scheme into a new open-ended production subsidy (Köper, 2012). The argument is that the higher salience of climate change in the UK and the more pressing perception of urgency of the renewable energy targets (e.g. EU 20-20-20) made it easier for proponents to position offshore wind as a solution to this problem and achieve significant policy support for the up-scaling of OSW (e.g. by providing two ROCs) and in terms of achieving favourable changes to the institutional frameworks.

A second striking contrast between the two cases is the role of the Crown Estate in the UK in terms of brokering and facilitating the empowering of offshore wind. The Crown Estate portrays itself as a ‘proactive landlord’ and is involved in a variety of supportive actions in the offshore wind space. Far beyond simply agreeing contractual terms for developers to use the seabed, the Crown Estate works very closely alongside developers, helping them with consenting, co-invests together with project developers up to the point of consent and developed a new Zone Appraisal and Planning process (for Round 3 leases) hoped to reduce risks to project delivery and to accelerate the programme. The Crown Estate is also active in developing a UK supply chain for example by organising supply chain events to inform UK companies about potential opportunities posed by the offshore wind sector which draws new actors and resources into the offshore wind niche. The Crown Estate is also managing the Offshore Wind Developers Forum, is part of the Offshore Wind Cost Reduction Taskforce and has recently published its own analysis of how to reduce offshore wind costs. This active and forward-looking engagement of the Crown Estate especially in the Round 3 leases has been praised as a “visionary, bold step which has moved the whole industry on” (interviewee 5) and has been heralded as really making a positive impact on where offshore wind is today (interviewee 8). Over the period under study, the Crown Estate has been highly involved in nurturing work (e.g. engaging in learning about cost reduction potentials; working closely with and investing alongside developers), as well as shielding and empowering work (e.g. as a source of expertise for the government and other public bodies; increasing legitimacy of the niche by helping to develop a UK supply chain). Conceptually, this role can be interpreted as what Hughes has called a ‘system builder’ (Hughes, 1979) who related ‘everything to a single central vision’ (that offshore wind should play a key role in the future UK electricity supply), reached out beyond their special competences and played an entrepreneurial, system building role. Not only is this type of actor absent in the Dutch case, but also some of the functions it fulfils (e.g. in terms of brokering, facilitating, having a commercial interest in the exploitation of the UK’s exclusive economic zone) do not exist in the Netherlands. In The Netherlands, the Department of Public Works (Rijkswaterstaat) fulfils some of these functions but is set up very differently (as a statutory actor) and is therefore not able to play a more active or promoting role in offshore wind.

6. Conclusion

This paper has analysed the developments of offshore wind in the UK and the Netherlands. We have sought to explain the divergence between rapid deployment of the technology in the UK in recent years and the stagnant developments in the Netherlands in terms of Smith and Raven (2012)’s concept of empowering.

Firstly, the analysis found that in The Netherlands, empowering strategies have largely shifted from ‘stretch-and-transform’ to ‘fit-and-conform’ over the period under study. Initially viewed as “necessary for urgent reasons of great public gravity”, offshore wind deployment fell victim to alternating political support and opposition, exemplified by an intermittent series of fundamentally different renewable energy subsidy schemes, which inspired little confidence in (regime) actors to invest. In recent years, empowering has been decidedly ‘fit-and-conform’ in nature, with support measures being geared towards offshore wind becoming competitive under conventional, incumbent regime terms. The focus shifted to innovation aimed at cost reduction: roll-out will only take place if and when costs have come down substantially. As such, offshore wind in The Netherlands is currently under pressure to become competitive on the more narrow techno-economic criteria of the existing energy system (Smith and Raven, 2012), compared to the broader sustainability values that originally prompted the ‘flight offshore’: unless these criteria are met, up-scaling will not be (financially) supported by the government. Sustainability has become subordinate to innovation, and offshore wind has to some extent become emblematic of a more ‘hands off’ policy approach (e.g. a bottom-up offshore wind industry-research coalition having inspired a new type of institutional actor (TKI) under the new top sector policy).

Conversely, in the UK ‘stretch-and-transform’ empowering has been quite successful. Environmental values were institutionalized in the form of the Renewables Obligation, which was designed to encourage generation of electricity from renewable sources. Empowering work resulted in offshore wind being awarded two Renewables Obligation Certificates per MWh produced, which inclined regime actors more favourably towards investments in offshore wind. Offshore wind has increasingly become a realistic resolution to uncertainties and tensions (e.g. the energy gap) experienced by these regime actors. In the UK, offshore wind has gradually become emblematic of sustainable energy production to the extent that it currently informs institutional reform processes (though it does not necessarily *drive* these (Smith, Stirling et al. 2005)).

How was it that in the UK, institutional change was effectuated while this did not succeed in The Netherlands? For this, we need to turn to the actors behind the narratives. As Smith and Raven (2012: 3031) argue, “[r]eforming institutions or creating new institutions requires power, expressed through the mobilisation of material and nonmaterial resources, and collective action capable of shaping norms, standards and routines in transformed regimes”. In the preceding section, we have already pointed to the presence of a powerful and resource-full actor which is present in The UK but absent in The Netherlands. The Crown Estate is a global actor (in terms of the distinction between local and global niche actors) which acted as an offshore wind ‘system builder’ (Jacobsson *et al.* 2004; Hughes, 1979), in the sense that it was financially and politically powerful enough to create the ideal conditions for large-scale roll-out to occur (even though had been set up as an independent company to create revenue for the Treasury, and had no specific sustainability agenda).

Our findings also indicate that Smith and Raven (2012)'s empowering perspective, which focuses analytical attention primarily on actors, their networks and the narratives they articulate, fails to capture a number of other factors which were found to be important in explaining the differences between developments in the UK and the Netherlands. These include:

- Competing issues on the policy agenda (the state of the economy, the financial crisis), as well as competing solutions to one and the same policy problem (e.g. the construction of new coal-fired power plants which mitigate energy security concerns in The Netherlands) both shape the context within which actor's empowerment strategies play out and can render them more or less effective.
- Different institutional settings shape the possibilities for empowering work. For example, the institutionalisation of concerns about climate change in the UK's DECC keeps this issue on the agenda even during times when other concerns dominate public discussions.

We therefore suggest an amendment of the framework: it seems necessary to take into account the wider institutional set up and contexts within which empowering work is enacted, as the institutional framework shapes and constrains actors' room to manoeuvre (Kern 2011). While these dynamics will empirically differ across countries and technologies, such an amended framework should provide an adequate heuristic to study the empowering of different low-carbon innovations as well.

Secondly, we engage with the debate around the national focus of many transition studies (Markard et al. 2012; Raven et al. 2012). By conducting a cross-country comparative study, we show that despite the highly international nature of the offshore wind sector, attempts by multi-national companies active across different jurisdictions to empower niche upscaling led to different outcomes in different countries. Therefore we argue that a conceptualization of protective space as being bounded in particular national jurisdictions can still be valid. This re-enforces the point made above about the importance of different institutional settings. A key-question is how different scales of innovation become (dis-) connected, i.e. how international networks and institutions become entangled with national and local ones, which kind of tensions are produced in such entanglements and how those are explanatory in understanding technological innovation trajectories.

Thirdly, the above findings suggest a number of avenues for future research. One interesting issue to explore is the interactions between different low carbon technologies and how the empowering dynamics of different low carbon technologies within the same and across different jurisdictions have an influence on the development of these niches. Another interesting avenue to explore further is the 'spatial switching' of key actors (such as Shell, DONG, Vattenfall) across a number of different jurisdictions. Our analysis showed these actors to be active in different jurisdictions at different points in time. It would be interesting to explore in more detail what influences the strategies of these actors and conversely what the impact of this switching is on the development of protective space in different national jurisdictions.

Appendix A: interviewees

Semi-structured, 'expert' interviews in the UK:

1	Representative of Energy Technologies Institute
2	Representative of Technology Strategy Board
3	Senior Official from Department of Business, Innovation and Skills
4	Member of Department of Energy and Climate Change's offshore wind taskforce
5	Engineering Manager at wind energy technology company
6	Strategy and Stakeholder Coordination Manager at a large utility company
7	Commercial manager at a renewable energy centre
8	Manager at renewable energy developer
9	Former DONG employee involved in economic and financial evaluations of offshore wind
10	Senior researcher involved in wind energy research
11	Senior researcher involved in wind energy research
12	Professor involved in wind energy research; also involved in European Wind Energy Association
13	Senior Official from Department of Energy and Climate Change

Semi-structured, 'expert' interviews in the Netherlands:

14	Offshore wind park design manager at marine contractor
15	CEO of offshore wind turbine producer
16	Senior development manager at energy company
17	Head of offshore wind business development at energy company
18	Researcher at environmental science institute
19	Director of multiparty offshore wind consortium
20	Offshore wind licencing manager at Department of Public Works
21	Policy advisor for department of Public Works *(informal interview)*

Unstructured, 'key informant' interview with experience in both countries:

22	Former senior manager at international oil firm with experience in offshore wind projects both in the UK and the Netherlands

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Submission No. 254

Modeling lead market based export potentials for OECD and Newly Industrializing countries – a system dynamics approach for wind turbines

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Abstract:

Markets for more environmentally products and services have been recognized as major areas of growth in modern economies. An important argument is that countries and/or industrial sectors which develop eco-innovations will gain several advantages. They will be well placed to export goods into the expanding international markets for clean intermediate and consumption goods, thus securing economic growth and generating new employment. Also, they will have the potential for a major reduction in their need for fossil fuels and other raw materials, vital to the functioning of the economy. Traditionally, it is thought that countries of the North will be the supplier of eco-innovations. However, with increasing globalization, there is growing strength of the technological capabilities in some countries of the South.

The paper explores the concepts of an innovation driven export potential, and presents the different factors which have to be taken into account. A system dynamics based modeling tool for wind energy technologies is presented which takes the various factors of export success into account.

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Keywords: wind energy; lead market; first mover advantage; absorptive capacity; trade pattern; economic development; system dynamics model.

1 Introduction

Markets for more environmentally products and services have been recognized as major areas of growth in modern economies. An important argument in the policy debate is that countries and/or industrial sectors which develop eco-innovations will gain two distinct advantages:

- They will have the potential for a major reduction in their need for fossil fuels and other raw materials, vital to the functioning of the economy and therefore a national concern.
- Also, they will be well placed to export goods into the expanding international markets for clean intermediate and consumption goods, thus securing economic growth and generating new employment.

Indeed, the idea of realizing first-mover advantages by developing lead markets has become very prominent in the justifications of technology and innovation policies. Traditionally, it is thought that countries of the North will be the supplier of eco-innovations. However, with increasing globalization, and the growing strength of the technological capabilities in the countries of the South, the integration of these innovations into the development process in the rapidly growing economies becomes an additional option which combines both economic catch-up with environmental sustainability.

Innovation based export success are linked to the notion of lead markets and first-mover advantages in foreign trade: it is argued that the trade patterns for technologies are also determined by the quality of the technology and its innovative character. Thus, high international market shares depend on the innovation ability and the achieved learning effects. If a country forges ahead in a specific technology, it tends to specialize early in the supply of the necessary technologies. According to the logic of a first-mover advantage, these countries are then in a good position to dominate international competition due to their early presence in this field (Porter and Van der Linde 2005). Furthermore, countries which are early followers and which are able to catch up technologically very quickly can also be able to achieve success on the world market.

There have been numerous studies looking at the macroeconomic effect of climate policies (for an overview see Walz and Schleich 2009 and Walz 2011). However, almost all of them neglect the effects of a lead market driven additional exports. A system dynamics based modeling tool for wind energy technologies is presented which takes the various factors of lead market driven export success into account.

1.1 Conceptual Model

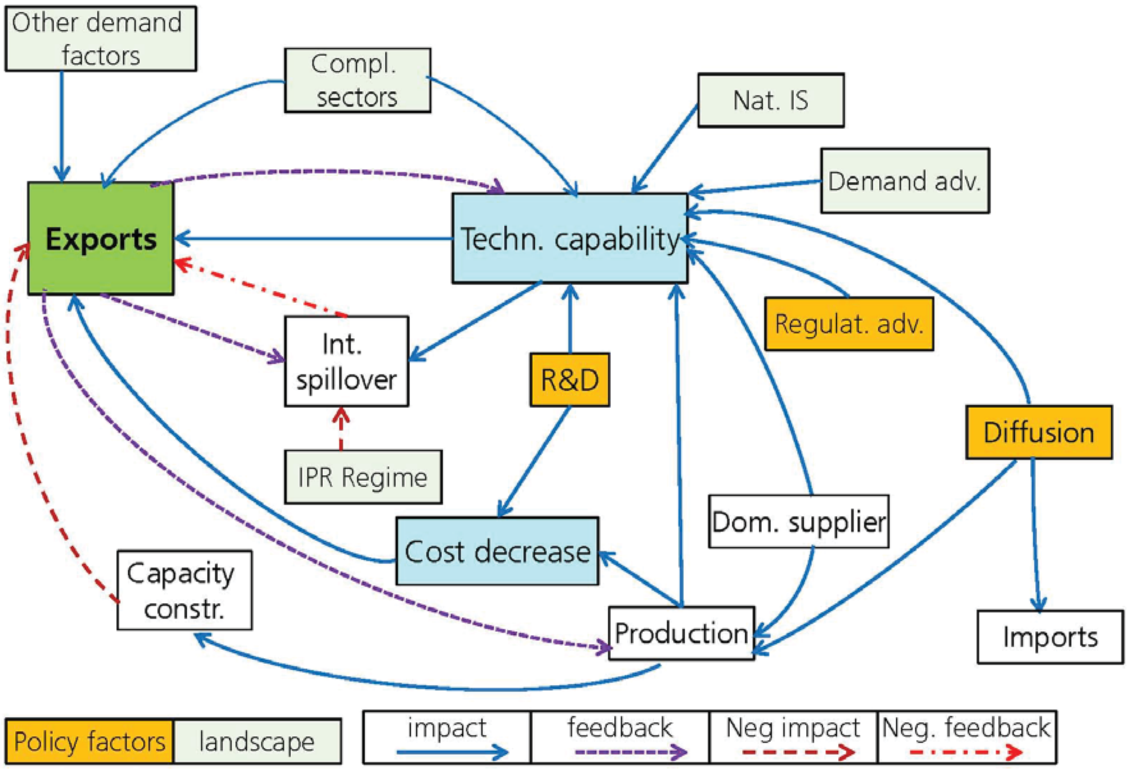
There are various success factors for lead market factors described in the latest working papers and presentations on lead markets. In addition to the demand oriented lead market factors, which have been proposed by Beise and Renning, there are also more supply side oriented factors such as technological capability with regard to the analysed technology, and competitive complementary clusters which allow for knowledge spillovers. They export and literature variables described above can be condensed in the conceptual model shown in Figure 1. The model consists of the factors described above. They can be influenced directly by the stringency and the design of policies in the field of the analyzed technology. Thus, the R&D levels (R&D programs for the technology), the diffusion of the technology (which is driven due to the externality problems by environmental policy) and the regulatory advantage are classified as policy factors. Other factors are rather exogenous from the technology analyzed. The factors are linked to each other by either positive or negative impacts (negative meaning that the increase in the causing factor leads to a decrease in the dependent factor). These impacts are not unidirectional: There are also positive and negative feedbacks, which lead to feedback loops within the system.

The conceptual model consists of the following factors and impacts:

- The exports are influenced by technological competences (which can be described as patents) and cost decreases.
- R&D subsidies are an important policy factor, which enhances both the number of patents and cost decreases.
- The diffusion of the technology in the country is directly influenced by environmental and sector policies. It leads to demand for the technology, which can be either produced domestically or is imported. Furthermore, exports must also be produced domestically.
- The level of domestic production leads to scale effects and thus cost/price advantages. Furthermore, it enables learning by doing leading to new patents.

- The level of domestic diffusion will also influence user-producer interaction, which will lead to additional knowledge and increases in technological capability.
- The national innovation system (NIS) influences the innovation capability of a country as a whole. Thus, even though this factor is not technology specific, it also influences the level of increase in technological capability in a country in the analyzed technology.
- The regulatory advantage consists of an innovation friendly regulatory regime. This will lead to a better innovation performance and higher technological capability.
- The level of domestic production requires the existence of domestic suppliers. Furthermore, the level of technological capability is also influenced by the structure among these key actors. Thus, if domestic suppliers and a competitive market structure emerge, the level of both domestic production and technological capability will increase.
- The other demand factors described above (demand, transfer and export advantage) address the ability of a country to develop a market which takes up global demands and international preferences earlier than others, and the demonstration and credibility of these advantages. Thus, they directly influence the amount of exports of the country.
- The technological capability also benefits from knowledge spillovers from complementary sectors. Thus, the stronger the complementary sectors, the higher will be the technological capability in the analyzed technology.
- The importance of the various forms of international knowledge spillovers has been described above. Thus, an increase in exports will lead to higher spillovers from capital embodied knowledge. Furthermore, technological capability which is protected by patents nevertheless leads to disclosure of existing knowledge and thus potential knowledge spillover. However, the stronger the protection of intellectual property rights, the less pronounced are these effects.
- The capacity constraints described above are impeding the level of exports. They are acting as an upper limit to exports as long as the increase in domestic production capability cannot keep pace with the increase in demand.

Figure 1: Conceptual model for explaining export shares for eco-innovation

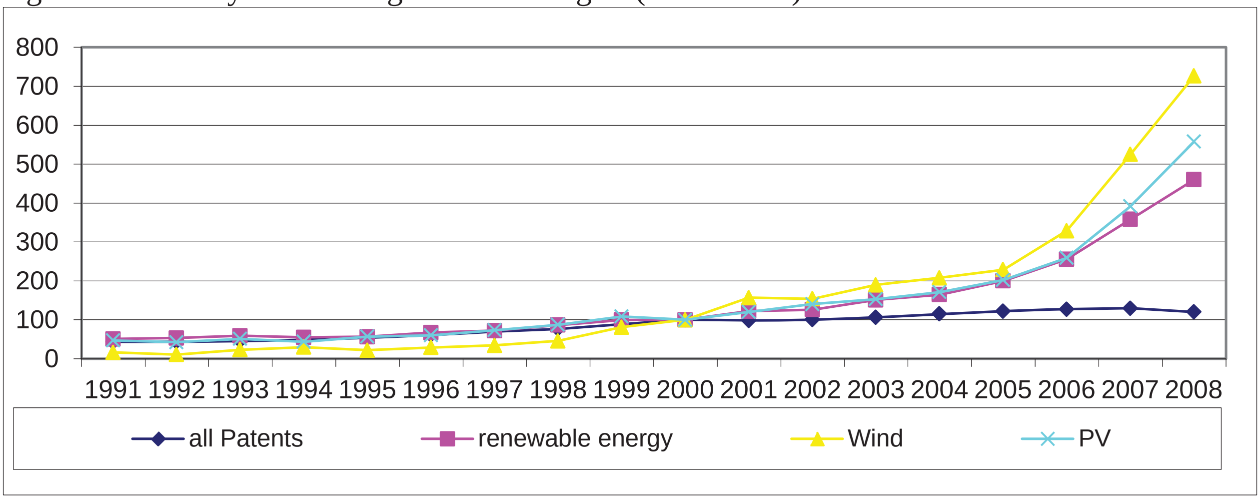


2 Wind turbine industry

2.1 Development of Markets

Most renewable energy technologies are closely related to the electrical and non-electrical machinery industry, which has been classified by the OECD as medium-high tech (Hatzichronoglou, 1997; Grupp, 1998). Wind turbine manufacturing is not a mass industrial process to the same extent as PV production, and application of tacit knowledge makes technology transfer more difficult (McInerney, 2011). Comparing wind turbine patent development with all patents indicates rather high innovation dynamics. Renewable energy technologies show very strong dynamics, much stronger than the average patent dynamics (Figure 2). Of the various renewable energy technologies, wind energy has experienced even stronger dynamics in recent years, even above photovoltaics. This supports the analysis made by sector consultants which sees new generations of turbines in the pipeline (Roland Berger, 2011). Thus, new market entrants from NICs cannot count on the future market for wind turbines being driven solely by the cost competition of the existing technologies. This all underlines the necessity to develop a strong innovation system in order to become internationally successful.

Figure 2. Patent dynamics for green technologies (2000 = 100)

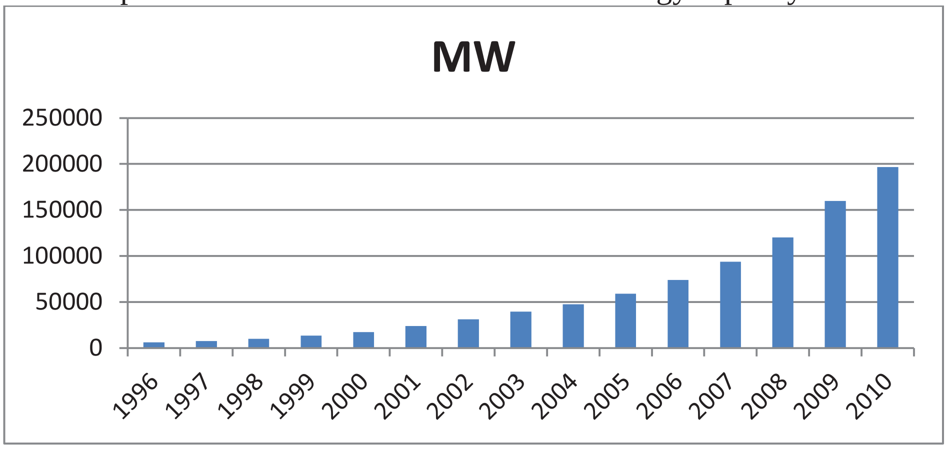


Source: calculations of Fraunhofer ISI

1203

Figure 3 demonstrates the enormous growth in the wind turbine industry over the last 15 years. Currently, there are about 200 GW of wind turbines installed globally. This growth has been driven by the German market in the early 2000s, followed by expansion in Spain and other European countries. Since the mid 2000s, the US, China and India have become important markets, too.

Figure 3. Development of accumulated installed wind energy capacity



Source: data from Global Wind Energy Council and World Wind Energy Association

The wind turbine industry developed around many newcomers in the field, which started as small companies. The industry has become more mature since then: Some of the early pioneers have grown into medium sized companies. There have been mergers between these pioneers and some of them have been taken over by more established players, such as General Electric and Siemens. Today, many of the leading companies operate international subsidiaries or are involved in joint ventures, and newcomers from China and India have been joining the playing field. The industry has become more international in its focus: According to UN-COMTRADE data, world exports of wind turbines grew from less than USD 400 million in 1996 to USD 1 billion in 2000 and around USD 5 billion in 2008.

Thus, the wind turbine industry has left its niche to become a very dynamic industry. Globalisation is a major factor within the industry, as is the emergence of China and India as major markets and important suppliers. This raises the question of how the export shares of the major suppliers will develop in the future.

2.2 Empirical case studies of development of wind energy industry

The heuristics of systems of innovation has been developed for national, sectoral and technological systems (see e.g. Lundvall et al., 2002; Edquist, 2005; Malerba, 2005; Carlsson et al., 2002). The innovation system concept also has great potential to analyse sustainability-oriented innovation systems. One aspect to consider within this framework is that innovations in such systems are typically more influenced by public needs and public discourse than “traditional” sectoral or technological innovation systems (Walz, 2007; Markard, 2011). The majority of applications in this field so far have been in the renewable energy field (Bergek and Jacobsson, 2003 and 2004; Agterbosch et al., 2004; Foxon et al., 2005; Negro et al., 2007 and 2008; Alkemade et al., 2007; Walz, 2007; Bergek et al., 2008a; Suurs and Hekkert, 2009; Jacobsson et al., 2009; Dantas, 2011; Mohamad, 2011). Some of these case studies have been focusing on the wind energy sector exclusively. In addition, there have been numerous case studies which looked at development of wind turbine markets and policies, which touched upon the same dynamics even though they were not using an explicit systems of innovation approach (Bird et al. 2005; Lewis and Wiser, 2007; Meyer 2004; Szarka2006). These case studies have shown that the actors and the networks which they are forming are important success factors. In addition, the institutions of the innovation system, and the policy factors described in chapter 2 in particular, are crucial for the development of the system. The development of the system does not follow a linear path, but is subject to the various feedback mechanisms.

In the latest years, various case studies have extended the scope of study of wind energy towards NICs (Changliang and Zhanfeng (2009); Kristinsson and Rao (2007) Purohit (2009); Rao and Kishore 2009; Yu and Zheng 2011; Zhang et al. 2009, Lewis 2011; Walz and Delgado 2012; Rasmus et al. 2012;). By and large, these analysis also show that the success factors identified for the OECD countries also play a role in the catch up process in NICs in wind energy industry.

In addition to case study evidence, the determinants of innovation in the OECD countries have also been analyzed in econometric studies (Johnstone et al., 2010; Walz et al., 2011). The empirical evidence suggests a strong impact of policy on innovations in renewable energy technologies for power generation. Both public R&D spending as well as policies which induce domestic demand increase the innovation activities. Likewise, policy factors such as introducing targets for renewable energy and providing stable policy support lead to higher innovation output. There is also empirical evidence that success on international markets seems to foster further innovations.

To sum up the experience, there is ample case study evidence which supports the importance of the above mentioned success factors. Given this ample experience, wind energy seems to be a particularly promising example to start with first modeling exercises of innovation driven export success.

3 Modeling of innovation-based export potential

Considering innovations as a process characterized by numerous feedbacks, the factors which influence the export success are also subject to the numerous feedbacks within a successful functioning system of innovation. Thus, modeling such a system poses considerable challenges:

- the modeling approach must account for the various feedback mechanisms,
- it must be able to model the development of the various factors over time, and
- it must be flexible and must allow access to different levels of data (e.g. quantitative established relationships, but also qualitative information).

Moving from conceptual analysis and empirical case studies towards modeling is a huge challenge which poses many threats. Parallel experience gained in case studies, and in-depth sector know-how with regard to technology development, actors, and policies is a prerequisite to reduce the risks that the modeling will lead to artefacts. Thus, the wind turbine industry was used by the authors for starting with modeling exercises. It is characterized by ample empirical results which were used to check the plausibility of the results (see section 4.2), and prior experience of the author team in this sector.

System dynamics is a modeling approach which fulfills these requirements. It is a methodology designed to improve the understanding of complex systems over time. It is widely used in management, natural sciences but also increasingly in economics. It accounts for the influence of random effects, does not necessarily lead to equilibrium solutions like traditional economic models, and highlights the adaptation processes.

The core variables of system dynamics are stocks and flows, with the flows determining the levels of the stocks. Essential to this methodology is the use of time delays and feedback loops (with feedback loops being a consequence of time delays). Thus, a level variable can directly or indirectly influence itself. The system behavior is influenced by both exogenous factors, which by definition are not affected by the system, and endogenous factors, which are modeled with various feedback mechanisms within the system. Feedback mechanisms can be either positive (the influenced variable changes in the same direction as the influencing variable) or negative (the influenced variable changes in the opposite direction to the influencing variable). The relations between the variables are modeled with mathematical functions, which can also allow for non-linear behavior. Furthermore, the complex interplay of the various feedback mechanisms allows building complex vicious or enhancing feedback circles.

In the previous sections, the factors for a first mover advantage were discussed. In order to integrate them into a system dynamic model for the export shares of countries for wind energy technologies, they are grouped into the following building blocks:

- The exports shares of the countries are explained by the model.
- The price advantage indicates the extent to which an increase in demand drives down costs and enables supplier to reduce prices. A typical approach to assess the reduction in costs according to increasing demand are learning curves (see McDonald and Schrattenholzer 2001; Berglund and Söderholm 2006; Köhler et al 2006; Uyterlinde et al. 2007 (Pan and Köhler 2007; Jamasb and Köhler 2008). The price factor was modeled according to a two-factor learning curve, which is driven by total diffusion (including exports) and R&D expenditures of the respective countries (Walz and Ragwitz 2012). The price effect directly affects exports.
- The demand advantage is attributed to countries where society and markets are more open than others towards future challenges. Wind energy is an important aspect of a technology which contributes to environmental sustainability. Thus, countries forging ahead with regard to taking sustainability issues into account can be adjudged in general to have a demand advantage. The demand advantage was modeled using results from a sustainability index (see Walz et al. 2010; Peuckert 2011). For this index, 55 countries are taken into account, comprising OECD countries as well as NICs and a few developing countries for which the indicator values are available.
- The transfer advantage depicts a demonstration effect and also depends on the technological reputation of the country. If countries are assigned a high technological reputation, they also have a transfer advantage. For modeling the transfer advantage, the index constructed by Peuckert (2011) was used as data.
- The export advantage describes the advantages of a country due to its openness. The share of R&D intensive exports at the GDP of the countries is used as an indicator. The higher this value, the stronger is the economy shaped by the demands from abroad.
- The patents represent the technological capabilities. They are influenced by R&D expenditures, the diffusion of the technology, and also the innovation friendliness of regulation (see Walz et al. 2011). The patents itself drive both the RPA (specialization) and the patent intensity, which influence exports.

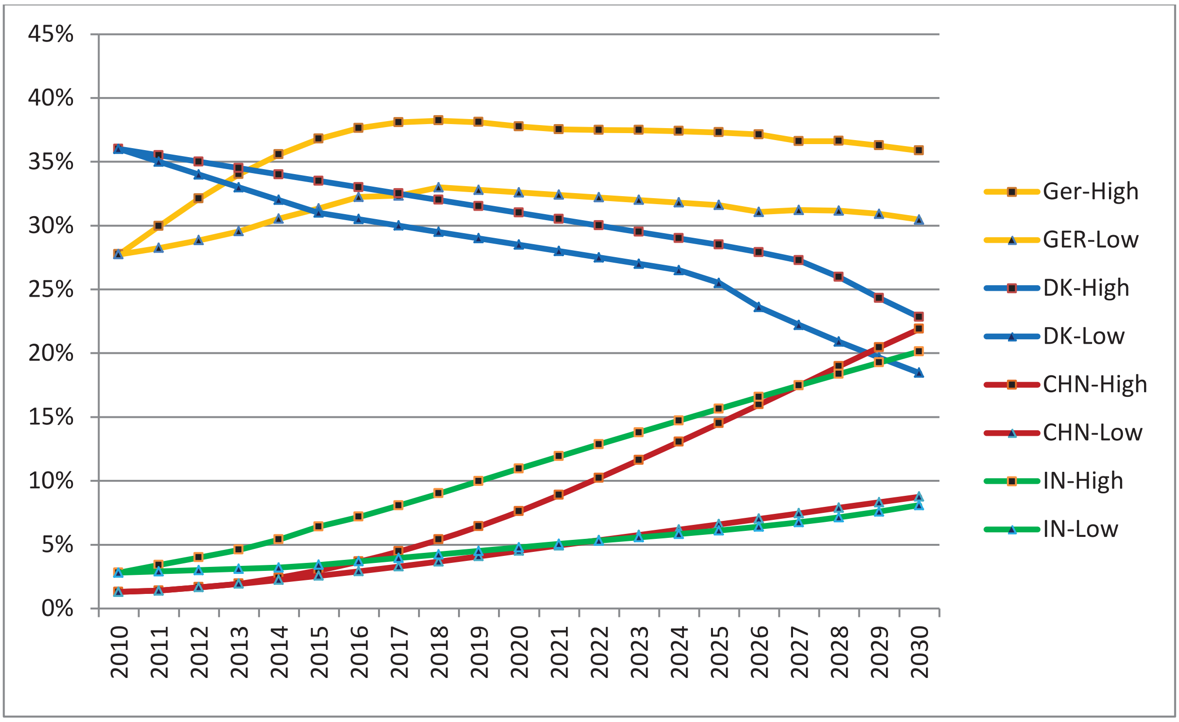
- The regulation comprises the factors which can be directly influenced by policy, e.g. R&D support, diffusion of the technology, but also soft context factors such as the policy style and the long-term character of the policy. The indicators used are derived from Walz et al. (2011).
- It is widely held that innovation and economic success also depend on how a specific technology is embedded into other relevant industry clusters. Machinery is an important complementary sector for wind turbine industry. In order to give an overview about the empirical situation, the RCA of machinery industry was used.
- International spillovers refer to the knowledge which is transferred to other countries. They are induced by various mechanisms ranging from access to codified knowledge (e.g. patents) to capital embodied knowledge (e.g. import of wind energy technologies). They are modeled as direct feedback loops.
- In order to account for capacity restraints in increasing exports, a slowing down of maximum exports function was introduced.

The model was developed for the case of wind turbines exports for large OECD countries which traditionally supply technologies (US, Japan, Germany, UK, France and Italy). Furthermore, Denmark and Spain, which both are important producers of wind turbines, were included, plus China and India as the two most important suppliers from the NICs. Finally, the rest of the countries were included as an aggregated block (rest of the world). Thus, the model calculates export shares on a world wide level simultaneously.

A system dynamics model essentially consists of a set of mathematical equations, each using input data to produce a result. The factors described above have been quantified using a series of proxies for the indicators. Depending on data availability, various adjustments had to be made. In addition, the functional form of the feedback loops had to be specified. The calibration of the model was using data for the years 1995-2007.

A first model run was implemented using the data from Ragwitz et al. (2010) and IEA (2009) for future diffusion of technology until the year 2030. Additional exogenous data input was changed with regard to finding out whether or not the model reacts on changing factors such as R&D intensity. Examples from the results of these model runs are shown in Figure 4 for selected countries. The results show the highest and lowest export shares for the countries, which resulted from the different variations in the model runs. They results indicate a reduction of the export shares of the first mover Denmark, a leveling off of the increase in export shares for the second mover Germany, and a catching up of the NICs China and India, respectively. Furthermore, the differences in results indicate the importance of variation of the factors. However, these results do not reflect a change in all possible input parameters. Thus, the results cannot be interpreted as a consistent scenario run, but only reflect how the model reacts on perceived changes of crucial variables. Thus future work will concentrate on a further fine-tuning of the model, and a subsequent analysis of consistent scenarios.

Figure 4: Explanatory scenarios for export shares in wind turbines depending on variables changed in first sensitivity analysis with the export model



Source: calculations of Fraunhofer ISI

4 Discussion and summary

The previous sections have presented the factors which influence the potential to establish export success in innovation driven technologies. These factors can be derived from the evolutionary theory of trade developed in the 1980’s. Various empirical results have corroborated this approach.

Moving from conceptual analysis and empirical case studies towards modeling is a huge challenge which poses many threats. Parallel experience with case studies, and in-depth sector know-how with regard to technology development, actors, and policies is a prerequisite to reduce the risks that the modeling will lead to artefacts. Thus, the wind turbine industry was used for starting with modeling exercises. It is characterized by ample empirical results, which were used to check the plausibility of the results, and prior experience of the authors in this sector.

The innovations process is characterized by numerous feedbacks. Thus, the factors which influence the export potential are also subject to the numerous feedbacks within a successful functioning system of innovation. Modeling such a system poses considerable challenges: First, the modeling approach must account for the various feedback mechanisms. Second, it must be able to model the development of the various factors over time, and third, it must be flexible and must allow access to different levels of data. In contrast to the traditional approaches which are used for economic forecasting, such as econometric or general equilibrium models, system dynamics is a more flexible modeling approach which fulfills these requirements. It is a methodology designed to improve the understanding of complex systems over time. It is widely used in management, natural sciences but also increasingly in economics. It accounts for the influence of random effects, does not necessarily lead to equilibrium solutions like traditional economic models and highlights the adaptation processes. However, the results from such modeling cannot be interpreted as forecasts. The results are rather possible scenarios which highlight the system dynamics and the internal logic used to describe the processes.

The system dynamics model uses the time between 1995 and 2007 as calibration period, and covers the time range until 2030. It has been successfully implemented for 8 OECD countries, China, India and the rest of the world. It shows that China and India will grasp a higher share of exports, with Denmark and – in the long run – Germany losing shares. If key variables are changed, the model shows the expected signs of changes. Future work will consist in fine-tuning the model, building consistent scenarios and performing the model runs for them. Furthermore, it will be necessary to think about how additional factors, such as the existence and structure of entrepreneurial actors, can be included in the model.

It is too early to base robust policy advice on these model runs alone. Nevertheless, the existing results already underline important conclusions: If newly industrializing countries are moving towards sustainable form of energy supply within their countries, and link this to an industrial policy which benefits selected renewable energy industries, environmental improvement is likely to come together with economic success. The system dynamics, which shows up in the case studies and the model, unequivocally call attention to a systemic policy approach: Policies on the supply side, which aim at establishing a domestic supply industry and fostering its capabilities, must be supplemented with demand policies, which create a domestic market and open up learning possibilities and scale effects. A key challenge will be how to integrate various policy arenas and how to come up with case specific policy mixes. The specific design of these policy mixes is beyond the aggregation level of modeling, and apt to case studies and policy design and evaluation studies. However, the model points toward that the substantial export increase, which are used to add economic justifications of such a policy to the environmental ones, are more than only a mere hope, but a realistic perspective.

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“The Future is not what it used to be”: School Pupils’ visions and Transition Pathways across 6 EU countries

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Full Paper, Contribution 307

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Abstract

There is a prima facie argument that those who are affected by a decision should have a say in that decision. In terms of intergenerational equity, as well as the evolution and implementation of the Transition Management agenda, this must include young people, which is also typically not pursued, as the majority of Visions and Transition Strategies are developed, often for good reasons, by experts and specialists in relevant fields. In addition, given the socio-cultural context, approach to technology etc, Generation Z is likely to have very different notions of their specific future, and the way sustainability and low-carbon lifestyles are evolving within this. This opens up the distinct possibility that (older) experts devise and shape transition pathways that hopefully deliver greater sustainability and less carbon-intensive lifestyles, but do so in a governance void and in a direction that those who are destined to live (in) these futures find difficult to accept, let alone actively pursue. In short, not involving young people in the Transition Pathways and Management agenda risk a governance deficit as well as an implementation challenge.

To understand how young people conceptualise of their future in low-carbon sustainability terms, and how they conceive suitable visions of their futures, 24 visioning workshops were held in Greece, Hungary, Lithuania, Norway, The Netherlands and the UK. This, then has allowed a comparison of their visions with those of more traditional and mainstream origins. Condensing these workshop-level visions, which produced over 1500 ideas and suggestions across the workshops, into pan-European Visions yielded three archetypical visions, namely Local Commuity, I-Tech, and One Ethical World. In addition, several observations about the perceptions of the pupils about their (sustainable) futures and were collated and digested. For instance, contrary to perceptions about the fully-connected lifestyles of modern pupils, issue they were apprehensive about was the rapid pace of technological change; fearing isolation and “not being able to keep up”.

Following this, an innovative new methodology to engage young people (and experts) in the development of suitable pathways towards the attainment of these visions were developed. A special focus on this are the implications (and transition pathways towards) specific sectors, notably household energy, mobility and food. This involved a pre-selection of “Pathway Components” – aspects of future visions or of the current status quo that act as drivers, barriers or system preconditions across the multi-level perspective. Such an approach then also allows a comparison of different Pathways, as well as of the role and significance of different Branching Points across pathways.

The paper outlines the visions, the pupils’ perception of the future and evaluates the adopted pathway methodology in detail.

Introduction

For many reasons, the efforts to make sense of, and influence, the future has been a dominant activity in planning of all sophisticated civilisations. In the absence of viable, functioning alternatives, societies looked to the past as a way to figure out the future thus relying on a continuity of many societal parameters. However, this paper will begin its discussion by arguing that traditional efforts to pursue such endeavours are inapplicable, and inappropriate for today, not only because we know that the past is unlikely to be a useful guide for the future, but also because we do not want the past to continue.

The rate of technological change, innovation and the dynamics of organisational and societal change is at a compelling, transitional pace. Concerns of globalisation, rapid and profound technological change, societies that age at unprecedented pace, mass customisation, social mobility across borders and cultures, the separation of place and content of work and a debt burden that effectively prohibits substantial reallocation of (non-existing) funds put together ensure that probably the most accurate prediction we can make about the future is that it will not look anything like the past.

In addition, there are many issues that require fundamental change to lifestyles, industrial organisation, governance and cultures, such as climate change, biodiversity loss, water access, fisheries and many more, which pose substantial challenges for the future:

> *Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber, and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth. The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs in the form of the degradation of many ecosystem services, increased risks of nonlinear changes, and the exacerbation of poverty for some groups of people. These problems, unless addressed, will substantially diminish the benefits that future generations obtain from ecosystems. (MEA, 2005, pg 4)*

To provide an impression of the scale of the challenge, the report estimates about 60% of ecosystem services are “degraded or used unsustainably”.

Equally, the persisting widespread poverty in all non-developing and most developing countries ask pertinent and demanding questions for our *ability to meet the needs of the present without compromising the ability of future generations to meet their own needs* (WCED 1987, pg 47) as we are not only unlikely to meet the future generations’ needs, we are palpably unable to do this for a substantial part of our current generation, which was already clear when the Brundtland report was written 25 years ago.

As a result of this combination of factors that reduce the accuracy of predictions and the need to develop future pathways that are structurally and systemically different to a continuation of past development trajectories, there is an urgent need for new futures. Some of these have made their way into policy already. For instance, the UK was the first country to introduce a legally binding target of an 80% reduction of greenhouse gas emissions by 2050, based on 1990 baseline (2008 Climate Change Act). This is mirrored in the EU 2050 roadmap, which also calls for interim targets of 25% by 2020, 40% by 2030 and 60% by 2040, in addition to the need to develop viable transition scenarios (EU Commission, 2011). In addition, there are many further national policies in many other countries that have set targets, often ambitious ones, towards the reduction of the environmental impact lifestyles and consumption habits have on ecosystems.

However, there are many possible scenarios of how we may live in a future where these and many correlated policies will have been achieved, as well as many different pathways that can lead towards this ambition. In addition, there are many further “wicked problems” that arise from these scenarios as well as possible corresponding pathways even if progress in some areas is already noticeable: The EU states that the interim target of a 25% reduction by 2020 shows a “generally solid initial start at EU level but with slower than expected removal of key barriers to renewable energy growth, with additional efforts by particular Member States being necessary” (EU Commission, 2013, p.2). Taking energy and climate change as an example, these policies can be achieved by a shift in the national energy mix, such as focusing substantially more on nuclear (which is probably one of the trajectories of France and the UK), greater emphasis on renewables and international trade (Germany), a shift away from coal (UK), greater energy efficiency (Netherlands) and many more. Emerging problems, such as energy security which is much more complex with renewables, also have different possible responses, including a potential reconsideration of national strategic fuel reserves, greater electricity grid integration, a new role for utility companies as providers of back-up power in a decentralized electricity production regime, or a reduction in the need for backup due to reduced reliance on electricity. However, the role of utilities, the governance of energy provision, the contribution of consumers (as consumers or as producers and consumers) and lifestyle changes are certain to be aspects of different futures that will need to be discussed as well as settled over time (Tukker et al 2008; Foxon et al 2009; Foxon 2010).

As a wider point, such development of new approaches should combine many relevant stakeholders, should integrate different dimensions of sustainability, and should include supply and demand of consumption systems (Quist et al 2006).

Given this range of flexibility and potential avenues, there remains substantial uncertainty about what precisely to do, and how to best move towards which kind of future scenario. This then also rests on two conclusions, namely that traditional planning tools are less suitable, and that those who are living in these futures should have a say in what these futures should be, and how to get there. This paper is contributing to this discussion by providing one possible methodology that addresses these conclusions, including the future scenarios that were developed, and a reflection on their suitability. An outlook of how transition pathways can be developed towards these futures is concluding the paper.

The Case for Young People Involvement

All initiatives to develop such futures and corresponding strategies for their attainment are necessarily social processes (Quist et al 2006), which suggests that deliberative processes are key even if the role of experts, and the knowledge and expertise gradient between laypeople and experts add to the design complexity of such processes. It is argued here that these social processes should involve young people. This is for several reasons:

First and foremost, it is a basic tenet of equity and equitable decision-making that people who are affected by decisions should have a say in it. This moral and sometimes legal right is the basis of (local) government, and it is the cornerstone of democratic deliberation and decision-making. Although futurity is a vexing problem in sustainable development generally – how can we ensure resources are available for future generations if we don’t know what they want (and have a long record of getting such predictions wrong). But where a dialogue with future generations is a logical impossibility, an engagement with the current public that will live in the future is not. Anecdotal observation of those currently active in the Transition Management and the backcasting movements suggests that very few who are active here are likely to live in 2050, let alone participate in the debate as part of their working lives. Therefore, involving young people in shaping such futures is essentially an ethical requirement – after all, it is their future that is being shaped.

Secondly, there is an underlying assumption of most stakeholder engagement that policies and strategies that have been developed with different stakeholders (as opposed to policies that were developed in isolation – or even defiance – of stakeholders) have a somewhat better chance for their implementation. This argument is at the minimum about “gaining buy-in” to a process, but it also blends the deliberation with the implementation process. Having said this, acceptability or even desirability of decisions may not necessarily be the essential feature of a successful and, in this context, radical change.

Likewise, stakeholder engagement is often associated with “better” decisions, as the inclusion of a wide variety of concerns, insights and reflections allows for a more tested and thus more robust understanding of the context and its strategies (Carlsson-Kanyama et al 2008). Relating this generic argument to the case for young people’s inclusion, the cultural, attitudinal and behavioural difference between "generation Z" and those currently involved with the development of different futures is profound, and the consideration of the former's viewpoints is potentially a vital "reality check" in the visioning of the latter.

Backcasting and Transition Management

As argued above, there is an urgent need to develop a better understanding and conceptualisation of "the future", actually, of different viable futures. These processes are by necessity and by design an inclusive, social process, which departs from traditional forecasting processes in a fundamental way, as these are evidently unreliable in fast-changing societal contexts, and are unsuitable if a continuation of the past is to be avoided. This has also been recognised by the many inclusive processes that have taken place over the years, such as national foresighting exercises (notably in South Africa, the UK, Germany, the Netherlands, but also in Jamaica, Mozambique and the Seychelles). In addition, the EU roadmap clearly calls for such visions of the future to be developed, and appropriate transition pathways to be conceived and promoted (EU Commission 2011).

The currently most promoted – and probably most suitable - process to enact this seems to be a combination of backcasting and Transition Management. One of the founding contributors of Backcasting defines the process as follows:

> *Backcasting is a methodology for planning under uncertain circumstances. In the context of sustainable development, it means to start planning from a description of the requirements that have to be met when society has successfully become sustainable, then the planning proceeds by linking today with tomorrow in a strategic way: what shall we do today to get there? What are the … instruments to make society ecologically and socially attractive?* (Holmberg et al, pg 293)

Conceptually, Quist et al (2006) identify 5 stages in participatory backcasting exercises:

1. *Strategic Problem orientation;*
2. *Construction of sustainable future visions or scenarios*
3. *Backcasting*
4. *Elaboration, analysis and defining follow-up and (action) agenda;*
5. *Embedding results and generating follow-up and implementation* (pg 1033)

This rather generic classification of steps has recently been enhanced by linking it to the transition and transition management approach. As a research and practice initiative, Transition Management focuses on the governance aspects of the managed process of societal transitions from one set of system dynamics to another (Foxon et al 2009). This accepts three interlocking and interactive features: firstly, societal change happens at different levels, often labelled niches (micro-level), regimes (meso level) and landscapes (Macro-level) (Rip et al 1998, Geels, 2002, 2005), including the dynamic interactions between and across these levels.

Secondly, change also happens at three different aspects of social systems, such as structures (policy frameworks, governance policies), cultures (personal ethics, local and global cultures) and practices (lifestyle patterns, our habits) (Sondeijker 2009), although some authors also refer to "technologies" instead of "practices" with (Martens et al 2002, Geels, 2005). Thirdly, the dynamics of change where whole-system level change is said to undergo 4 distinct transition phases named Pre-development (the initial state of the system in question), Take-off (where individual niche activities begin to become mainstream); Acceleration (where the moves out into the societal system as a whole, triggering further changes and introducing a certain irreversibility of the indusced change) and Stabilisation, where society embarks on a new state of dynamic stability (Geels 2005, Sondeijker 2009).

It should be noted that this picture of transitioning societies is not without conflict and disagreement, where factors (structures / cultures / processes) driving change at different levels are in conflict with factors resisting change. As a result, the success of the "take-off" and "acceleration" stages often depend on the relative success of these factors to cross levels, overcome inertia and resistance and "mainstream" lower-level successes which in turn depends on the framework conditions that allowed the individual niche activities to become successful to be "mainstreamed" as well (van den Bosch et al, 2005; Foxon 2010).

In addition, the multi-actor perspective, that recognises the importance of a diverse and dynamic set of stakeholders and their specific, typically overlapping networks is recognised as a vital ingredient. However, it is not immediately clear whether this element of the emerging Transition Management school is rooted in the participatory dimension of the backcasting methodology, or are part of the Transitions Theory on how societal whole-systems can or should change. It is also not essential to attribute this to one or the other root, as it is a core element for either – and this debate.

As a result, the linking of Backcasting and Transition Management is yielding a complex picture of the inner logic and the dynamics of societal change at different levels, with bespoke aspects and transitioning through a broadly defined set of stages. In this, Backcasting becomes embedded into a wider (Transition Management) process, and contributes by (a) developing a social understanding of the need for change, and developing (in participatory processes) the visions (or scenarios in the earlier backcasting projects) towards which change is to happen, as well as (b) outlining the initial building blocks or factors that need to be changed for the mainstreaming of niches to become successful (and the vision to be realised).

The CRISP approach to backcasting

Here, following the definition of Holmberg above, as well as the synthesis of Backcasting and Transition Management outlined above, the process CRISP adopted to CReate Innovative Sustainability Pathways consisted of three three specific steps, namely visioning, backcasting and transition planning:

- Visioning: Developing a set of visions or scenarios for what we would like the future to be. These are typically aspirational, and developed without considering what we have today, or where we are today. Typically, several visions were prepared.
- Backcasting: Establishing steps of how we would get there – what are the intermediary stages between today and these visions.
- Transition planning: Formulating a Transition Pathway that promotes the backcasting stages.

These steps are homoform to Quist's 5-step methodology although this sequence has not the separation of the 4th and 5th step Quist et al are promoting. These steps also fit with other documented cases (van den Bosch et al 2005; Carlsson-Kanyama 2008; Holmberg et al 2000 etc)

In practice, workshops with predominantly school teenagers but also other laypeople were conducted who attended the last year before potentially entering University. The workshops were held in a mixture of urban and rural contexts in Greece, Hungary, Lithuania, the Netherlands, Norway and UK; and across a range of social strata although each country did not span across the social divide. In addition, some schools were more innovative in their philosophy to teaching than others. Most workshops were gender mixed, although not all. No compensation for such diversity in workshop context and composition was made as each idea and output from the workshops were seen as equal and was anonymised in the collation of results from the workshops. A favourable ethical opinion was sought (and found) prior to the workshop, and individual, parental as well as full school consent were given in writing beforehand. Some supervision and attendance of teachers were also offered and a small number of workshops took this opportunity up.

Results of the Backcasting processes

The workshops were tasked to brainstorm "ideas or any aspects of a sustainable and desirable future", with an emphasis on three specific sectors (mobility, household energy and food) and each workshop tried then to develop a set of intrinsically consistent scenarios based on a group clustering technique. Different to other workshops, no voting n the individual ideas took place. The 12 workshops in the 6 countries produced about 1500 individual ideas, although a number of duplicates were inevitable between workshops.

Following this stage, all ideas and workshop scenarios were then put together, and the CRISP project team condensed the multiplicity of ideas and scenarios into three overarching “end-visions”, namely (in no order) *Local Community*, *iTech,* and *one Ethical World.* Their narrative includes a short focusing on the three sectors and they are presented in Boxes 1-3, respectively. After this stage, the three endvisions were converted into three shot animation videos, following the idea of van de Kerkhof et al (2005) outlining the need for visualisation in participatory processes, and in general recognition that young people may not read as many transition management visions but may find their animation on youtube more accessible.

It should be noted that the difference in content between these visions and visions developed by, or in participation with, experts is unexpectedly small. Similar or comparable visions have been developed by many others, but the important point here is less its similarity, but the ability of young people to constructively and purposefully think about (their own) future with results that are as robust (or lack thereof) as that of experts.

Some workshops defined “sustainable futures” in idiosyncratic manners, for example one pushed a proto-luddite agrarian vision of the future that blended “sustainable” with “subsistence” uncomfortably. Another workshop took the current rapid pace of technological change to its logical extreme and argued that, technologically, if anything is possible, everything becomes feasible, and a plethora of innovations became the basis of a society that lived in open defiance of the Laws of Thermodynamics and well beyond its biophysical limits. But the experience has shown that these issues are concerns of the problem framing and of prior understanding of the meaning and challenge of sustainable development and sustainable consumption.

The development of transition pathways is subject to subsequent steps that do not form part of this discussion.

Box 1: CRISP 2030 Vision: *Local Community*

2030 is characterised by living in dense communities, organised into regions and clusters. Social cohesion is strong, with an emphasis on local cultural identity, local use of resources, family. Generally, social relationships being of critical importance: Citizens take responsibility for sustainable living and actively pursue a sustainable, slower, healthy lifestyle based on "less": People consume less food, less mobility, and much less household energy. As a result, each community is characterised by a unique fabric and social, technical and individual landscape, which is reinforced and amplified by strong social cohesion.

The underpinning reason for this is the effort to utilise available resources and technology in the most efficient way: Communities are largely self-sufficient in terms of products and services, shift of monetary transactions to collaborative consumption and sharing products and services (e.g. cooperatives) within and between the communities. All these kind of services have to be facilitated by ICT and regulation.

Every region is dependent on local resources, skills and social capital that result in differences in their development within a larger network. There is limited trade for essentials that cannot be supplied locally. Education from a very young age promotes self-reliant society, people engage in life-long learning and aim to improve professionally and fulfill their dreams, aspirations, develop creativity, individual skills and self-development. People look for meaningful (as opposed to materially enriching) work and strive for a good balance between work and personal life.

These societies are communal and frugal, with engaged and environmentally-literate citizens who understand the human effects on environment and society. Since the economy is based on the local area and self-sufficiency, very efficient use of resources is needed, including minimisation/re-use of waste; companies are small-scale. More transactions are undertaken without use of money (e.g. barter, *favour bank*); society is seen as a communal pool of assets to be drawn upon. Overall, the community is seen as a big family in which people look out for each other. This also makes these communities highly diverse and individualistic between them.

Social cohesion in these clustered communities, be they urban or rural, is strong, and most local consumption is also locally produced. Collaborative consumption (sharing, exchange, lending) is frequent with many products traded directly within the community. This requires (and is supported by) and governance for self-organisation. As a result, the work-life balance is also much more, well, balanced.

With regard to **food**, local food and decreasing foodmiles is a central feature. This has been achieved through corner shops, farmers' markets, but also a strong preference for vegetarian food. Locally produced insects are a popular source of protein supplementing the seasonal varieties of food after most meat and fish consumption was scaled down due to animal welfare concerns. A large part of food production is subsistence (garden, roof and wall gardens, community gardens). Different to the past, production here is not for an anonymous market, but production is for a purpose. Food is a communal focus point, and its consumption takes place in communities and communal spaces that have replaced earlier fast food restaurants.

From a **technology** perspective, environmental progress has taken priority over economic progress but rather than having significant rates of technological progress, communities rely on existing technology, using it more efficiently, and more tailored to local conditions and needs.

Mobility needs are much reduced and moved away form individual motorised modes: people prefer to work closer to the place where they live, products and services based locally, but for the mobility needs that remain, subsidised public transport in parallel to cycling are the most popular forms. Car use has been limited to emergencies and far-away places that are otherwise difficult to reach, although car sharing is popular on these routes.

Household energy is locally produced, but energy demand is also reduced through more efficient energy use, warmer clothing and improved insulation. Urban planning based on the ideas of sustainable development has supported this, with extensive waste avoidance and re-use, as well as re-use of grey and rain water and a proliferation of green spaces in towns.

Box 2: CRISP 2030 Vision: *iTech*

Here, technology has been recognised as the dominant driver of lifestyle changes and the resource productivity that underpins consumption globally. There is ever-greater reliance on technological solutions for social, political, personal and technological solutions and on the continuous development of new gizmos, gadgets and gear that have reached every part of everybody's life.

Likewise, new technology has become a value ad a status symbol in its own right and companies as well as individuals driving innovation and technological solutions are highly regarded. In fact, the transformative nature of technology itself is acknowledged and appreciated – in a way, society globally celebrates Schumpeter's disruptive technology and creative destruction. High tech sustainable solutions are common. There is a strong focus on solutions rather than on process improvement. The focus of the society is the education in order to develop very well educated and highly skilled people and renewables as well as new business models on cradle to cradle and other innovative concepts means that there is practically no waste. New multipurpose materials are used for may applications.

With regard to mobility, regions and economies benefit from the migration of the information intelligentsia to these areas. High tech sustainable mobility mentally as well as physically, unrestricted; encouraged by very high speed (and not very expensive) transportation means (trains, ships, friction-free vehicles) that will be able to transfer people from one place to another in very few minutes. In other words, public transport is considerably cheaper, much more available and faster (Magnetic railways), cars will not rely on the combustion engine, but individual transport will be more expensive than in 2012. World trade agreements on patenting and technology development and transfer have become dominant policy issues between countries and regions. Beyond physical meetings, technology also facilitates the communication between living in distant places and speaking different languages (3D holograms?). They may communicate speaking their own language and the other people automatically listen in their own language. This results in global community and a somewhat reduced need to travel physically in the first place.

With regard to food, technology has transformed the way we produce and consume food radically as well: Functional food and drinks (high energy low calorie) dominate the market and new and novel tastes and foods are continuously developed and jostle for market shares. Because of the pressures for instantaneous gratification, cheap and readily available food accessible to everybody but cooked food that is specially prepared is a luxury habit in rather expensive restaurants. Modern, smart kitchens have self cleaning equipment, multiple functions and high energy efficiency characteristics that help to organize and keep a healthy diet, buy food and monitor the food eaten. Food production relies on meat production without animals needed, food pills, high tech food production, with extensive use of high-tech to maintain appropriate conditions in greenhouses, on roofs or in gardens for the local production of food. Use of i-technology to make food last longer, thus reducing waste and increasing access.

With regard to household energy, houses are intelligent and smart: they follow global standards with all kinds of digital and holographic devices and services making everyday life easier and cleaner (clean, cook, organize everything); giving advice on and monitoring the use of water and energy. Almost all accommodation is "energy plus", due to a mixture of improved insulation, reduced energy consumption and much more efficient local energy production; PV and solar panels are integrated in the material and the construction of the houses, geothermal energy, small wind turbines are used for the production and consumption of energy for the community. At the same time the planning on a global scale has indicated locations for large scale RES projects to provide cheap and clean energy to everyone. Water will be transported through energy efficient networks from areas that have water surplus to other arid areas of Europe. Also, water needs will be covered by purifying grey and rain water for secondary uses.

Typical technologies include:

- Renewables (cradle to cradle, upcycling, solar energy, wave, tidal water and wind power, hydro energy, bio energy, geo energy) sustainable materials from waste, production algae for biofuels, renewing water by using toilet-filters.
- High tech substitutes (energy pills, food pills, personal holographic presentation in relation to distant working, open –person solar vehicles, artificial muscle mass as a substitute for meat, hi-tech solutions that experiences the tastes of the past, magnet trains, submarine tunnels, jet packs, nano, and GMO technologies, solar, floating houses.

Non-invented technologies: one person cabin that can use GPS without rails and can mix pedestrians with cyclists, nano-sized solar cells, voice-activated cooking systems, underwater cars, flying cars, mopeds and horses, underwater cars, cars with muscles, holiday simulators, raw materials from other planets, changing CO_2into energy, amphibious vehicles. Insulation materials on roofs and terraces change colour depending on weather conditions thus reducing the need for heating and cooling. Energy production embedded in the materials.

Box 3: CRISP 2030 Vision: One "Ethical" World

The overall vision is that of a fairer, more equitable world: The great divisions between rich and poor, developed and developing world are dramatically reduced. A growing ethical movement and a growing influence from civil society and citizens in response to global economic, societal, and ecological trends are informed by a global vision of global justice. This vision is shaped by ethics with mutual re-enforcement between ethically informed behaviour and political leadership. The public demands a responsible and transparent government and political process. Adaptive and reflexive institutions initiate dialogue and greater interaction between the macro, meso and micro levels. There are recognised global laws giving rights to everyone and greater standards of equality. People co-operate with *their* government, because they see politicians are acting in a collective rather than self-interest. People put more trust in the political process.

Global production is based on Fair Trade, because with global allocation/distribution of renewable energy comes global co-ordination and governance. There is equity in the allocation and distribution of resources with different regions providing or receiving according to their capabilities and needs. This global distribution has allowed an optimization of life-cycle impacts that would be impossible locally or regionally. Greater ecological stability, a reduction in excessive pollution, and greater care for endangered species, forms the basis of a more sustainable society. More economic and political cooperation between countries and most aid will get to the citizens that need it more.

Globally, accommodating a growing global population is a central political concern with more provision for people's needs and developing a decent standard of living for all. Communications between countries is easier and languages are more recognised and taught. A global land and resources allocation system operates: a central and strategic land use plan will allocate specific areas in Europe for organic food production, but also for energy production and heavy industry. The EU is integral part of the world network of material, information and energy flows, but it has developed a strong reputation for being a leader in behavior (as opposed to technology) driven change. Issues and concerns of specific regions are not ignored or set aside for a greater good, but they are simply not as relevant or material in the policy process. Social innovation has largely superseded technological innovation. Still, countries cooperate to promote projects for ongoing sustainable future. Responsibility for the societal, economic, and ecological well-being is shared globally rather than regionally. Global sports events help foster a sense of global unity and cooperation.

Unsustainable behaviour is frowned upon with regulation/taxation supporting such social values: For example, individual transport is seen as selfish and most commuters prefer working online in the daily (public transport) commute or exercise by cycling or running to the workplace. There are also fairer career salaries and a chance for everyone to earn a better wage for their work. Less social discrimination means a more optimistic population keen to work and earn their own money. A strong welfare system underpins these aims with better income distribution and a more efficient / fair benefits system to support those unable to work. A global health care system, and a cure for all illnesses, such as AIDS, a very low global crime rates and all nuclear weapons are destroyed, promoting global peace.

Of course, **mobility** is important globally and within regions to develop links between countries around trade, politics and education. Cheaper tourism to increase income in destination countries also lets more people enjoy different cultures. People use more sustainable forms of transport wherever options exist, and extensive infrastructural support is provided for more sustainable forms of mobility. In addition, connecting via communication technology rather than travel is encouraged.

Some **food** will be more expensive, such as meat and fish. Others part will remain cheap because it is produced ethically in areas with location advantages. Food production becomes health- and less profit-driven. There will be more home cooking and less use of 'fast food' restaurants which encourage intensive farming and more food miles.

Consumers are encouraged to reduce domestic **energy** use, both via information and education and through policy measures to discourage inefficient domestic energy consumption, in addition to decreasing use of non-renewable energies and an increase in the use of renewable energy sources, especially more alternative energy sources to petrol. Energy is generated globally in areas where the potential is the highest and will be distributed wherever needed.

Overall, greater understanding of the human effects of unsustainable development on the natural world exists, and people's energy choices are influenced by this higher awareness.

Reflections & Conclusions

For the most part, the pupils had no difficulties in engaging with the tasks at hand and with producing results that were innovative, constructive and suitable to the backcasting process at hand. Therefore, from a performance and delivery aspect, there is no *prima facie* case against greater involvement of young people in the (Transition) Management of their futures. Given the important benefits participation can have in policy, this is to be welcomed.

Likewise, even though the workshops were very different, expressing ideas about the future in a very creative way is not easy. Maybe it is in the balancing and smoothing nature of participatory backcasting exercises that radical visions of very different futures were difficult to find.

It was encouraging to see that almost all students across the workshops and countries consistently displayed a strong sense of community and of social concern, be this in the group dynamics during the workshops, or in the content of their visions. Corresponding to this, there was no socio-economic gradient in the kind of things students envisioned. However, there was a gradient in the depth of their visions. This social concern, and the degree of "blindness" towards class is in stark contrast to the prejudice about the self-indulgent and "me-driven", hedonistic youth culture of "Generation X". Pupils were competent and showed critical thinking as well as a willingness to engage with *their* future.

A persistent feature the emerged in the overall discussion about the workshop results is the somewhat ambivalent relationship the young workshop participants had towards technology. It is also the "known unknown" in future visioning, where reliable ideas of the pace and direction of such change are rare. Given the pace of innovation and of technology change, some students felt this was dominating their futures and most felt they had no influence in the direction or pace of technological innovation. In fact, most felt excluded from the technological dynamism their parents prejudicially may feel is at the heart of their offspring's self-definition and culture.

"Living sustainably" has substantial overlap with "living simple lives in rural areas" or, *in extremis*, of "being poor in rural areas" in the views of many of the participants, regardless of the (continuing) desirability of urban, Western lifestyles, as unsustainable as they may be.

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